# EXPERT REPORT

Opinion re "Expert Report of Peter A. Erickson" April 12, 2018
Opinion re "Expert Report of Joseph E. Stiglitz" April 13, 2018

*Kelsey Cascadia Rose Juliana, et al. v. United States of America, et al.*

*Case No. 6:15-CV-01517-TC*

David G. Victor

Professor
University of California at San Diego
9500 Gilman Drive #0519
La Jolla, CA 92093

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David G. Victor

## I. INTRODUCTION

This expert report is submitted in connection with the matter known as *Kelsey Cascadia Rose Juliana; Xiuhtezcatl Tonatiuh M., through his Guardian Tamara Roske-Martinez; et al., v. The United States of America; Donald Trump, in his official capacity as President of the United States; et al., United States District Court, District of Oregon Case No. 6:15-cv-015-17-TC*. I have been asked to assess claims made by Peter A. Erickson, regarding the U.S. share of GHG emissions, the feasibility of transitioning to a consumption-based accounting system, and impacts on emissions from potential reforms to federal fossil fuel subsidies and leases, as proffered by Mr. Erickson in his Expert Report, dated April 12, 2018. I also have been asked to assess claims made by Joseph E. Stiglitz, regarding whether U.S. dependence on fossil fuels is an inevitable consequence of history, and whether the U.S. can adopt meaningful policy interventions to mitigate climate change without engaging with its international trading partners, as proffered by Dr. Stiglitz in his Expert Report, dated April 13, 2018. The opinions contained in this report are based on my professional knowledge, training, and experience. I reserve the right to supplement this report as additional information is made available.

## II. QUALIFICATIONS

I am a professor at UC San Diego where I teach international relations, energy policy and energy market design at the School of Global Policy and Strategy. I also am an adjunct Professor of Climate, Atmospheric Science and Physical Oceanography at the Scripps Institution of Oceanography. Formerly, I was a tenured full professor at Stanford Law School where I taught industrial organization and also led the Stanford University Program on Energy and Sustainable Development.

I am a nationally-recognized expert in energy and environmental policy, with more than thirty years of experience. I am the author or co-author/editor of eight (8) books and approximately 200 articles. My work has been cited more than 14,000 times (per Google Scholar). My curriculum vitae is included as Appendix A to this report, and a list of my publications from 2008 to the present is contained in Appendix B.

Since 1990, I have been actively involved in the Intergovernmental Panel on Climate Change (IPCC), the United Nations' body charged with periodically assessing the science of climate change, including the science underpinning control of emissions that contribute to climate change. In 2007, the IPCC won the Nobel Peace Prize for its work. I have been engaged in five (5) IPCC assessments, performing various author, contributor and reviewer roles. In the most recent IPCC assessment, concluded in 2014, I served as a convening lead author, the term the IPCC uses for assessment members who have greatest responsibility for the report. I also contributed to the two key summaries of the study—the "Summary for Policy Makers" and the "Technical Summary."

I have been Chairman and a member of the advisory board, as well as a member of the Board of Directors, for the Electric Power Research Institute (EPRI). EPRI is a non-profit organization established by US and global electric utilities for the purpose of conducting research on advanced electric power technologies. I am a member of the Global Future Council for the World Economic Forum, which convenes the annual industry leader event in Davos Switzerland.

For four years, I have served as a member of the advisory board of the Institute of Nuclear Power Operators (INPO), the organization established after Three Mile Island with the mission of independent oversight of the safe operation of all U.S. nuclear reactors. I chair the San Onofre Community Engagement Panel, which helps steward the safe closure and dismantlement of the San Onofre nuclear reactor complex located south of Los Angeles.

My undergraduate degree is in History and Science (Harvard), and my Ph.D. is in Political Science from the Massachusetts Institute of Technology (MIT).

I am a regular participant in academic, industry, and government studies on issues related to energy sources and energy systems in the U.S. and abroad. Examples of my participation include the Council on Foreign Relations Task Force regarding the national security consequences of US dependency on oil imports—I served as task force member and Chief of Staff with former Secretary of Defense Jim Schlesinger and former CIA Director John Deutch as co-chairs. At Stanford, I convened studies on the globalization of the natural gas market, the organization of the global oil industry, and the globalization of the coal market. I also served on the advisory board of the MIT study "The Future of Natural Gas," a major study looking at developments in the US and overseas gas markets. Most recently, I served as a panel member on the US National Research Council study on reliability and resilience of the U.S. power grid.

In addition to my work at UC San Diego, I am a nonresident senior fellow at the Brookings Institution. I am the co-chair and co-founder of the cross-Brookings initiative on energy and climate. The goal of this initiative is to rethink strategies for effective management of the climate change problem, within the U.S. and globally.

## III. SUMMARY OVERVIEW

The plaintiffs in this case have put forth a series of claims regarding the role played by the U.S. in global greenhouse gas (GHG) emissions, and potential pathways for addressing these emissions going forward. In my expert opinion, several assertions made by Mr. Peter A. Erickson in his Expert Report, dated April 12, 2018, are based on insufficient facts and data, and the incorrect application of generally accepted methods. Specifically, there are five topic areas discussed by Erickson in his Expert Report, upon which I believe his opinions cannot be reasonably relied.

First, with respect to the U.S. share of global emissions, it is my expert opinion that the analyses within Erickson's Expert Report obscures the scope and complexity of policy interventions needed to control emissions by improperly focusing only on energy-related combustion of fossil fuels. A full accounting of GHGs and emissions controls indicates that a wide range of industrial and agricultural activities and policies should be considered when deriving a total estimate of emissions. By failing to consider the full range of activities and gases that contribute to climate change, Erickson oversimplifies the scope of the actions necessary to decrease U.S. and global GHG emissions. Further, Erickson's own data, as well as the data I reference in this Expert Report, indicate that the U.S. constitutes only a small portion of global emissions. Even if the U.S. were to unilaterally eliminate all of its greenhouse gas emissions, 87 to 88% of global emissions still would remain. The facts support that the U.S. is just one of many emitters; and, in my view, action to limit climate change requires coordinated international action.

Second, with respect to claims regarding the use of consumption-based accounting methods for GHGs, it is my expert opinion that such methods are neither administratively, nor politically straightforward to implement quickly. Erickson oversimplifies the technical feasibility of the U.S. adopting a consumption-based inventory and accounting system. He also fails to articulate the length of time that will be needed to design and implement an accurate consumption-based accounting system. Importantly, Erickson fails to address a central challenge in implementing such a system: border adjustments to bring emission control incentives for imported products in line with products manufactured in the U.S. Further, Erickson's Expert Report fails to note that even if the U.S. were to shift to a consumption-based accounting system, such a shift would increase the share of global emissions attributed to the U.S. by only about 1%. As I stated previously, action to limit climate change requires coordinated international action, regardless of the accounting method adopted by the U.S.

Third, with respect to U.S. federal energy subsidies, I believe that Erickson's Expert Report is misleading and provides insufficient basis to support his claims. Erickson suggests that U.S. subsidization of energy is dominated by fossil fuels. I disagree. I estimate that: 1) federal fossil fuel subsidies are a tiny fraction of total value of the fossil fuel energy industry, and therefore not material to the industry's operations; and 2) Erickson appears to cherry-pick data that focuses on fossil energy subsidies, ignoring the substantial subsidies that exist for other elements of the energy system, including efficiency and renewable energy.

On a straight-dollar basis, I find that subsidies for renewable energy exceed subsidies for fossil energy by a factor of at least 2. Further, proportional to U.S. energy output, the tax-related subsidy for renewables is more than 50 times the level of tax-related subsidies for fossil fuels. When properly analyzed, the data indicate that U.S. subsidies have shifted, and continue to shift, in the direction of energy sources that require market support – away from fossil fuels, and towards renewables in support of a diversified energy portfolio.

Fourth, with respect to the impacts of federal subsidies on oil production, I find that Erickson selectively targeted data and tailored his methods to inflate the beneficial impacts of subsidy reform on fossil fuel consumption and associated emissions reductions. Erickson limits the bases of his opinion to one academic study and one commercial study, even though those and other reputable studies point to different conclusions. Notably, he is conspicuously silent regarding the range of expert views on the matter of subsidy reform in the oil production sector. My examination of these studies, as well as review of the studies that Erickson, himself, relies on as part of the basis for his conclusions, indicates that the effect of oil subsidy reforms on emissions will be small to zero. More broadly, the studies that Erickson cites in support of his analysis of the impacts of subsidies on oil production do not substantiate his claims, and serve to evince that this topic lacks clear-cut conclusions. Rather than subsidy policy, which is at the margin of key considerations for the fossil fuel sector, it is my opinion that market and technological forces mainly drive production, consumption, and emissions associated with the oil industry.

Fifth, with respect to the impacts of federal coal leasing policies, I again find that Erickson's conclusions are not supported by the breadth of nuanced research on this topic. In my expert opinion, wholesale reform of federal coal leasing policies warrants more rigorous analysis of attendant impacts than that presented by Erickson in his Expert Report. The foundation of Erickson's opinion is qualitative and focused on elementary economic logic that he mis-applies

to the coal market. In my expert opinion, it is probable that coal extraction will continue to decline over time, irrespective of federal coal leasing reforms or reversal of preferential tax-based subsidies.

I also examined the foundation of Joseph E. Stiglitz's assertion in his Expert Report, dated April 13, 2018, that the U.S. failed to take affirmative action to eliminate fossil fuels. I maintain that this assertion is ill-founded and not well-substantiated. Specifically, Stiglitz fails to identify plausible, real-world actions that the U.S. government could have taken that would have led to appreciably different outcomes with respect to domestic and international energy systems. It is my belief that the dependence on fossil fuels which existed prior to the oil crises of the 1970s, and which exists today, in fact, is the inevitable consequence of history, contrary to the Stiglitz assertion (page 12 in Stiglitz' Expert Report). My opinion is shared by nationally-recognized historians in energy technology.

In addition, Stiglitz fails to acknowledge that, in the late 1970s, when he asserts the U.S. failed to take affirmative actions to move off fossil fuels, there was little experience with renewables technology. What experience did exist suggests that such technologies could be as much as 25 times more costly than existing rival (fossil fuel) technologies. While advances in wind and solar technologies have facilitated, and will continue to facilitate, integration of renewables into the U.S. energy system, these technologies were cost-prohibitive in the 1970s, and the potential for their future performance was relatively unknown.

Finally, I find that Erickson and Stiglitz make key errors of omission, in their respective Expert Reports, by failing to note that climate change requires international cooperation, as a matter of foreign policy. In my expert opinion, effective solutions to mitigate the adverse impacts of climate change necessitate engaged cooperation between the U.S. and its international partners. Stiglitz suggests that the U.S. has been neglectful in the actions needed to achieve international cooperation on climate problems. I disagree. In fact, the U.S. has been at the forefront of efforts to engage with its trading partners on issues of global climate, including efforts associated with the Intergovernmental Panel on Climate Change (IPCC), the 1992 Framework Convention on Climate Change, and the 2015 Paris Agreement.

It is my expert opinion that the simplistic and narrowly-focused approaches posited by Stiglitz and Erickson with respect to U.S. engagement on the issue of climate change fails to appreciate the global nature of the problem and the need for a nuanced foreign policy strategy to obtain international cooperation. Below, I summarize the bases for my opinions in greater detail.

**Finding #1: THE SIZE AND COMPOSITION OF U.S. EMISSIONS NECESSITATES AN INTEGRATED SOLUTION, AND THE U.S. SHARE OF GLOBAL EMISSIONS IS DECLINING**

The Plaintiffs in this case have put forth that "the United States is responsible for more than a quarter of global historic cumulative $CO_2$ emissions."[1] The Federal Defendants have admitted that "from 1850 to 2012, $CO_2$ emissions from the United States (including from land use) constituted more than one-quarter of cumulative global $CO_2$ emissions."[2] The Expert Report of Mr. Peter A. Erickson, dated April 12, 2018, states:

> "The U.S. is responsible for a substantial amount of global GHG [Greenhouse Gas] emissions." (page 3)

I examined the data relied upon, and the techniques applied by, Erickson to support his conclusion. It is my expert opinion that Erickson's analysis of the size and composition of U.S. emissions obscures the scope and complexity of policy interventions needed to control those emissions. Further, even if the U.S. were to unilaterally eliminate all of its current GHG emissions, about 88% of global emissions would still remain.[3] I state the bases for my opinion below.

First, the data that Erickson presents as the basis for his opinion are for only a subset of greenhouse gases—industrial emissions of carbon dioxide ($CO_2$), mainly from burning fossil fuels.[4] In so doing, Erickson creates the impression that emissions control policies should pinpoint only energy-related combustion of fossil fuels and niche industrial activities, such as production of cement. This is incorrect, because Erickson's statistics exclude 35% of global emissions of GHGs, as shown in Figure 1 and explained below. A proper and full accounting shows there are many other GHGs that contribute to climate change, beyond the subset of emissions discussed by Erickson in his Expert Report. Further, in my view, emissions controls should implicate a range of industrial and agricultural activities in the United States and abroad. In fact, many other gases and sources beyond $CO_2$ from industrial sources should be considered when deriving a total estimate of GHG emissions—notably, methane ($CH_4$), nitrous oxide ($N_2O$), $CO_2$ from changes in land use, and so-called "F-gases" used in industrial operations. Scientific evidence shows that soot also has a large impact on climate change—most soot comes from biomass burning, combustion of diesel fuel, and a host of other activities in the US and abroad.[5]

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[1] First Amended Complaint for Declaratory and Injunctive Relief, *Kelsey Cascadia Rose Juliana, et al. v. United States of America et al., Case No. 6:15-CV-01517-TC*, Document No. 7, filed September 10, 2015, page 3, paragraph 7.

[2] Federal Defendants' Answer to First Amended Complaint for Declaratory and Injunctive Relief (ECF No. 7), *Kelsey Cascadia Rose Juliana, et al. v. United States of America et al., Case No. 6:15-CV-01517-TC*, Document No. 98, filed January 13, 2015, page 5, paragraph 7.

[3] See Figure 2 of this Expert Report for an explanation of the derivation of the 88% figure.

[4] The Erickson report presents data from the Carbon Dioxide Information Analysis Center (CDIAC) at the Oak Ridge National Laboratory (ORNL). The CDIAC data set, available at http://cdiac.ess-dive.lbl.gov/, is focused on fossil fuels and industry. It is necessary to look to other data sources to develop a complete picture of GHG emissions.

[5] T.C. Bond et al., "Bounding the role of black carbon in the climate system: A scientific assessment," *Journal of Geophysical Research:* Atmospheres 118:538-5552, 2013. Drew Shindell, et al., "Simultaneously Mitigating Near-

In my opinion, by failing to consider the full range of activities and GHGs that contribute to climate change, Erickson oversimplifies the scope of actions necessary to decrease global GHG emissions.

My opinion is supported by Figure 1, which shows the full accounting for global emissions, as reported in the latest assessment of the IPCC.[6] In my view, policy intervention to mitigate the growth of GHG emissions requires flexibility and should be broad in scope. Since 1990, the U.S. has been a leading advocate for such a "comprehensive approach" in emissions statistics and emissions control efforts.[7] The essence of the U.S. approach is that any effort to limit climate change should engage the full range of activities and GHGs that cause such change.

Specifically, I believe that the scope of policy intervention should include not just the whole of the energy system (a major source of $CO_2$ and $CH_4$), but also agriculture and land policies (a major source of $CH_4$ as well as $N_2O$ and soot and the carbon absorbed in soils and thus $CO_2$ emissions), air pollution policy (which affects $CH_4$ and soot), wastewater treatment (a source of $N_2O$ and $CH_4$), many manufacturing industries (where fluorinated "F-gases" are used along with cement where the chemistry of cement manufacture cases $CO_2$), and forestry (which affects carbon in soils and in above-ground timber). For these reasons, Erickson's oversimplification of the interventions necessary to achieve his stated reductions in GHG emissions fails to consider the breadth of necessary policy changes, and the complexity of interactions between energy systems and industrial sectors.

Term Climate Change and Improving Human Health and Food Security," *Science* 335(6065):183-189, Jan. 13, 2012. Jennifer Burney, Charles Kennel, and David G. Victor, "Getting serious about the new realities of global climate change," *Bulletin of the Atomic* Scientists 69(4):49-57, July 2013.

[6] Figure 1 is based on methods that are widely accepted and used by the United Nations Framework Convention on Climate Change, and by the United States Government. Those methods include 100-year "global warming potentials" to account for the fact that greenhouse gases differ in their impact on the climate, and in the time horizon or which the greenhouse gases live in the atmosphere. See *Working Group III Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, 2014, available online at: http://www.ipcc.ch/report/ar5/wg3/.

[7] Jonathan B. Wiener & Richard B. Stewart, The Comprehensive Approach to Global Climate Policy: Issues of Design and Practicality, 9 *Arizona Journal of International and Comparative Law* 83-113 (1992). David G. Victor, 1991, "Limits of Market-based Strategies for Slowing Global Warming: The Case of Tradeable Permits," *Policy Sciences*, vol. 24, pp. 199-222. Alan D Hecht and Dennis Tirpak. Framework Agreement on Climate Change: A Scientific and Policy History. 1995. 29 Climatic Change 371-402.

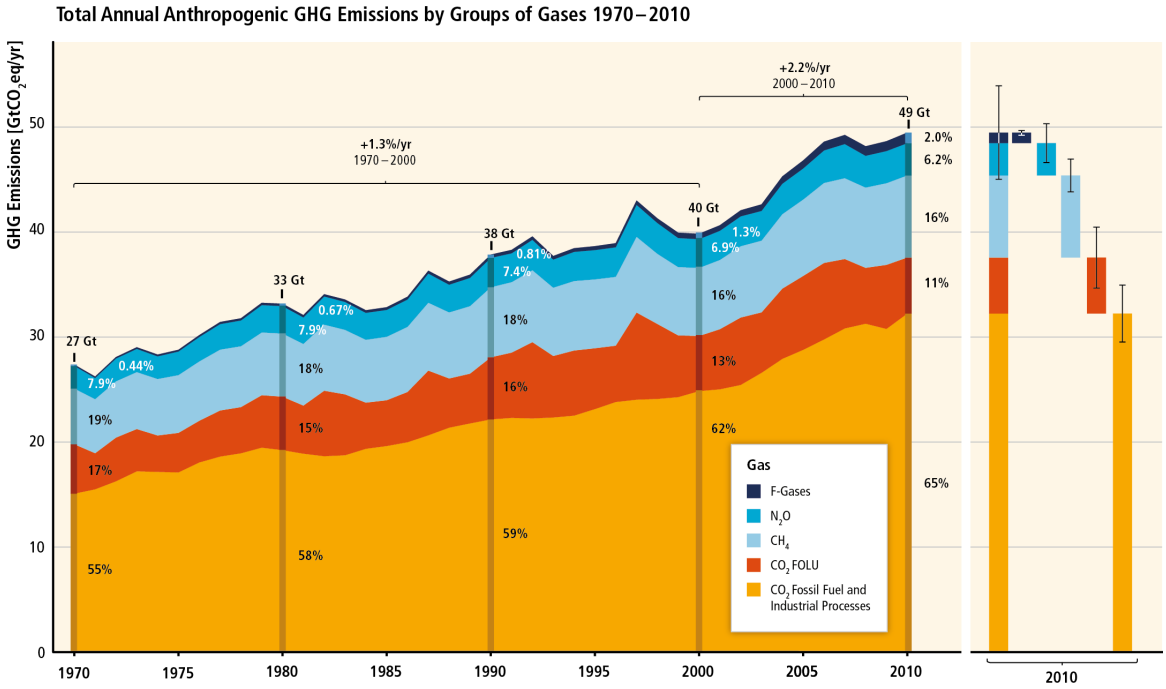


*Figure 1: Emissions of GHGs. Figure shows emissions of different GHGs converted into common units known as $CO_2$-equivalents ($CO_2e$). The waterfall on the right side of the chart indicates uncertainty in the global estimates for each of these emission sources. The percentages listed on the chart show the portion of global total emissions accounted for by each major type of emission at each decade. In 2010, 35% of total GHG emissions derived from sources that are expressly excluded from Erickson's analysis, and therefore his summary statistics. Source: Intergovernmental Panel on Climate Change, Working Group III Contribution to the Fifth Assessment Report, 2014, Chapter: Summary for Policy Makers, page 7, Figure 1, http://www.ipcc.ch/pdf/assessment-report/ar5/wg3/WGIIIAR5_SPM_TS_Volume.pdf.*

Second, Erickson presents data on emissions from the U.S. and other countries, asserting that "The U.S. remains the world's second largest emitter, and has been responsible for about 15% of global $CO_2$ emissions since 2010." (page 4) By ignoring trends over time, Erickson fails to articulate the fact that overall U.S. emissions contributions have been declining since 2005 (see inset to figure 2 below). With the decline in U.S. emissions, the ability of the U.S. to have an impact on the global problem through unilateral action has declined, as well.

Figure 2 charts all GHG emissions, unlike Erickson's data which are narrowly limited to $CO_2$ emissions from fossil fuels and industrial sources. As shown, the U.S. share of global GHG emissions has declined over the last decade. The decline in absolute level of U.S. emissions is due to several factors, including: (1) the shift from coal to inexpensive natural gas in the power sector; and (2) substantial expanded investment in renewable power.[8] The decline in the U.S.

[8] See also K. Larsen, J. Larsen, W. Herndon, S. Mohan, and T. Houser, *Taking Stock 2017: Adjusting Expectations for US GHG Emissions* (Rhodium Group, 2017). Carbon Dioxide Information Analysis Center, National $CO_2$ Emissions from Fossil-Fule Burning, Cement Manufacture, and Gas Flaring: 1751-2014, national-level dataset dated March 5,

share of global GHG emissions is due to two factors: (1) the decline in US absolute emissions; and (2) the increase in absolute emissions attributable to other countries, such as China and India.

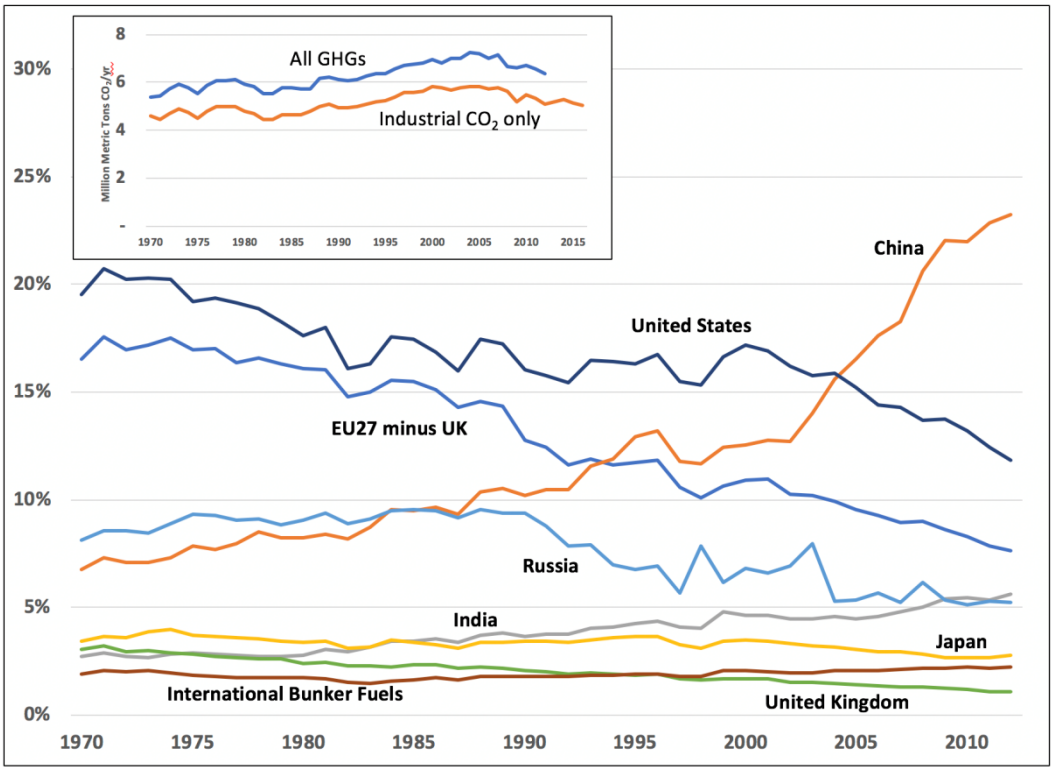


*Figure 2: Share of emissions from the U.S. and other countries that have important geopolitical impacts on efforts to cooperate on climate change, from 1970 to 2012. The timeline ends in 2012, with the U.S. share at 12%, which reflects the end point for the most reliable updates of the global data set for GHG emissions. Data for industrial $CO_2$ extends to 2016. Inset figure shows absolute emissions from the U.S. using two different accounting methods—top line includes all GHGs and is comparable with the main figure; the bottom line includes only sources of industrial $CO_2$ and is comparable with the data presented by Erickson. The "all GHGs" data in the EDGAR data sets exclude $CO_2$ emissions from short cycle biomass burning and exclude soot and other aerosols due to lack of data reliability and availability. The data in Figure 2 are drawn from the EDGAR system, which is notable for its coverage and comprehensiveness; EDGAR is the same source as that used for Figure 1.*[9]

2017, http://cdiac.ess-dive.lbl.gov/ftp/ndp030/nation.1751_2014.ems. These data indicate that U.S. emissions peaked at 1,578,873,000 metric tons of carbon in 2005, and have declined thereafter.

[9] Sources: EDGAR 4.2 FT2012 (all GHGs through 2012) and EDGAR 4.3.2 (industrial $CO_2$ up to 2016). Files are the GHG timeseries files at:

http://edgar.jrc.ec.europa.eu/overview.php?v=42FT2012

http://edgar.jrc.ec.europa.eu/overview.php?v=CO2andGHG1970-2016&dst=CO2emi

My analysis indicates that even if the U.S. eliminates all of its territorial GHG emissions, and by extension all of its $CO_2$ emissions, a substantial share (88%) of total global GHG emissions would remain. As shown in Figure 2, the U.S. is just one of many emitters, and action to limit climate change requires coordinated international action.

**Finding #2. IMPLEMENTING NEW CONSUMPTION-BASED ACCOUNTING METHODS FOR GREENHOUSE GASES IS NEITHER ADMINISTRATIVELY NOR POLITICALLY STRAIGHTFORWARD**

In his Expert Report, Erickson states:

> "Due to advances in the availability of trade and other economic data, consumption-based GHG inventories are not difficult to produce – especially at the national level, even as the concepts and models used to produce them can be complex." (page 11)

Erickson further states:

> "The most common approach is to use global trade data, assembled in a multi-regional input-output (MRIO) model, to estimate the flow of materials, goods, and services throughout the world in order to fulfill the consumption of a given country." (page 11)

Erickson concludes:

> "In my opinion, few if any technical barriers would prevent the Federal Defendants in this case, especially the U.S. EPA or U.S. DOE, from conducting both consumption-based and extraction-based inventories for the U.S."

I assessed the data summarized by Erickson in his Expert Report, and examined academic efforts to adopt consumption-based accounting systems. In my opinion, Erickson oversimplifies the technical feasibility of the U.S. adopting a supplemental, consumption-based GHG inventory. Even if feasible, Erickson fails to articulate the length of time that will be needed to design and implement a consumption-based accounting structure that: (1) accurately reflects the full range of GHG emissions; and (2) is implemented with data and cooperation from all significant trading partners of the United States. Further, Erickson fails to address the most important challenge in adopting a new accounting system – aligning the new system with border adjustments, such that imported products face the same emission control incentives as products manufactured in the U.S. In my expert opinion, even if the U.S. were to shift to a consumption-based accounting system, such a shift would affect the US share of global emissions by only about 1%. I summarize the bases for my opinions below.

I agree that, in theory, a shift in emissions accounting could shed light on the number of products consumed in the U.S. that contribute to emissions in territories outside the U.S. However, I

To compute the US share, on the GHG timeseries worksheet for the EDGAR 4.2 FT2012 dataset, divide cell AS22 (US emissions in 2012, which were 6343840 metric kilotons of CO2eq) into cell AS238 (global emissions in 2012, which were 53937188 metric kilotons of CO2eq).

believe that any change in accounting scheme also must contemplate adjustments in border tariffs, thereby creating the necessary incentives for all emitting firms, both global and domestic, to control their emissions. Simply adopting a new accounting system will not have much impact on behavior unless that system is coupled to incentives for firms and consumers to adjust their behavior to reflect the full range of consumption-based emissions. Such border adjustments are necessary so that U.S.-imported products face the same emission control incentives as products manufactured within the U.S. Without a comprehensive solution that addresses this differential in cost, the U.S. will be at an economic disadvantage vis-à-vis its international partners. This disadvantage will make it harder to create the global incentives needed for global emission reductions and will also exacerbate the political challenges of sustaining an effective climate policy in the U.S.[10]

Erickson asserts that "consumption-based GHG inventories are not difficult to produce." (page 11) As the basis for his opinion, Erickson presumes:

1. The technical computation of consumption-based statistics is "a relatively straight-forward process" (page 11), and the "[m]ethods for conducting them have been widely studied." (page 13). Erickson cites to academic studies as the basis for these assertions.

2. Other jurisdictions—such as the United Kingdom[11] and Oregon[12]—have conducted consumption-based inventory and accounting, suggesting that precedent exists and governments have overcome the technical challenges.

3. Border adjustments and tariff implications are not an impediment to advancement by virtue of remaining silent to such issues in his Expert Report.

I believe that Erickson's logic is faulty, and he fails to appreciate the complexity of adopting and implementing a consumption-based accounting system. Specifically, Erickson fails to recognize that, even with the agreement of its cooperative trading partners, it would take the U.S. one to two decades to implement an effective consumption-based accounting system. If the U.S. trading partners are not cooperative, then I believe that such a system would take even longer.[13]

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[10] Robert O. Keohane and David G. Victor, "Cooperation and discord in global climate policy," *Nature Climate Change* 6:570-575 (2016).

[11] United Kingdom Department for Environment Food & Rural Affairs, "UK's Carbon Footprint 1997-2015," available online at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/704607/Consumption_emissions_May18.pdf.

[12] Oregon Department of Environmental Quality, "Consumption-based Greenhouse Gas Emissions Inventory for Oregon," available online at: https://www.oregon.gov/DEQ/mm/Pages/Consumption-based-GHG.aspx

[13] A useful example of international cooperative engagement, and the magnitude of the challenges related to such, is the current effort by the American Institute of CPAs (AICPA) to converge International and U.S. Accounting Principles – alignment of U.S. generally-accepted accounting principles (or GAAP) and International Financial Reporting Standards (IFRS) set by the International Accounting Standards Board (IASB) in London, United Kingdom. The AICPA set a goal of "substantial completion of work" between the IASB and the Financial Accounting Standards Board (FASB) during 2013; this goal was supported by the G-20 group of countries, but convergence is still incomplete. The "Convergence Headquarters" webpage at IFRS.com, a site run by the IFRS Foundation (founded by

Presently, and for the foreseeable future, there are substantial technical and methodological challenges associated with adopting a consumption-based accounting system. I discuss these challenges in more detail below.

First, data are accessible for industrial $CO_2$ emissions, yet a serious and balanced policy strategy must address the full range of GHGs. The foundational studies on consumption-based accounting assess implications associated with industrial $CO_2$ and fail to assess other GHGs or polluting activities. For example, the UK accounting system purports to cover all GHGs. Yet, my assessment of the data reveals that the more detailed estimates within the UK analysis cover only industrial $CO_2$ emissions.[14] In my view, to implement consumption-based accounting in ways that actually influence the activities contributing to emissions, a broader accounting of GHGs is necessary than that which the current consumption-based accounting scheme can support.

Second, all of the extant accounting efforts, which form the basis for Erickson's opinion, are based on average emission factors. Specifically, these methods rely on average emission coefficients (e.g., for electric power) and average estimates for emissions caused by the production of different tradeable goods (e.g., steel, cement). This is standard practice for the input-output data sets and models that underlie the main studies on consumption-based accounting. Nonetheless, little attention has been paid to the limitations associated with relying on averages.

The practical implication of emissions averaging is that particular firms that are selling or buying products will have an incentive to claim that their production is less emissions intensive than the average. In some cases, those claims will be accurate. In other cases, firms will simply shift energy sources so that they assign "clean" production to traded goods, while using "dirty" production elsewhere. For example, a firm that produces energy-intensive products in China might claim that it is purchasing electricity from the Chinese grid with a contract that assigns nuclear power or renewable power to that firm, with no associated emissions. Yet, electrons are co-mingled on electric grids, and the Chinese grid, on average, is dominated by coal-fired power plants. How can the claim from the Chinese firm about its electricity supply contract be validated? In my view, efforts to develop consumption-based accounting systems have not

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AICPA), lists a series of updates between October 2012 and February 2015, none of which indicate the achievement of full convergence. The latest progress report from the IASB and FASB on the convergence of accounting standards dates back to 2010 (accessible at https://www.asb.or.jp/jp/wp-content/uploads/20100706_11.pdf). In 2016, the SEC Chair issued a public statement stating: "While it is now clear that U.S. GAAP and IFRS will continue to coexist in our public capital markets for the foreseeable future, it is just as clear that the efforts to enhance the respective standards and reduce differences between them should continue." The full statement is accessible at: https://www.sec.gov/news/statement/white-2016-01-05.html. The challenge of creating convergence and reliability in emissions statistics is much greater than for financial accounting because almost none of the foundation for detailed reporting of all underlying emissions, linked to particular firms and production methods, exists whereas the task of financial accounting convergence began after a comparable foundation was already in place.

[14] United Kingdom Department for Environment Food & Rural Affairs, "UK's Carbon Footprint 1997-2015," available online at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/704607/Consumption_emissions_May18.pdf.

addressed the challenge of moving beyond simple averages, and in so doing reducing the potential for leakage.

Simply ignoring the problem—as Erickson appears to do—raises the risk that the newly-instituted consumption-based accounting system would be deemed inconsistent with applicable trade law under the WTO. In practice, the WTO has allowed border measures, such as those which would be implemented through consumption-based accounting, but only if countries implement those border measures in ways that allow better-performing firms and governments to be treated differently from worse-performing counterparts. In my expert opinion, accounting systems should be designed to reflect real world behavior, and not simply rely on sectoral averages of unknown accuracy.[15] Quite apart from the question of WTO compliance is the matter of incentives. The purpose of a consumption-based accounting system is to create incentives for particular firms and consumers to adjust their behavior and reduce emissions in a cost-effective manner. Failure to create a sophisticated accounting system that allows individual firms to adjust their behavior and get credit for emissions lower than the sector average would undermine the very purpose of adopting a consumption-based accounting system in the first place.

Third, the data needed for a global consumption-based accounting system to be effective is substantial and obtaining such data from overseas producers would be challenging. For example, US-based administrators could not effectively review all relevant contracts for power supply in China in the example offered above. Although I focus on China, because its firms account for the largest share of emissions exported by virtue of the volume of products shipped to the U.S., for a consumption based accounting system to work, it would need to cover all significant trading partners of the United States. Some of the data collection apparatus exists under implementation of cross-border tax provisions. But, a similar infrastructure does not yet exist for the collection of global emissions factors and other needed statistics.

Further, with respect to Erickson's use of the UK model as a salient example of a successful consumption-based accounting system, the UK program is largely an academic, thought experiment. The UK model is focused on providing a complementary analysis of the UK "footprint" with respect to global climate change. The Oregon program cited by Erickson tends to be more transparent and routinized. However, it relies completely on sectoral averages, and for the reasons discussed above, this renders the Oregon model unreliable. In addition, the Oregon model fails to reveal how methodological challenges will be handled when individual producers have an incentive to deviate from those averages.[16]

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[15] For example, see the World Trade Organization (WTO) Report of the Appellate Body, "United States – Import Prohibition of Certain Shrimp and Shrimp Products," Report No. AB-1998-4, available online at: https://www.wto.org/english/tratop_e/dispu_e/58abr.pdf. While this entrains a number of legal and political issues outside the scope of my Expert Report, I note that a member of that WTO Appellate Body (Jim Bacchus) has written extensively about how the precedents created at the WTO allow for non-discriminatory border adjustments, including the border tax adjustments discussed in this report. See James Bacchus, on behalf of the E15 Expert Group on Measures to Address Climate Change and the Trade System, "Global Rules for Mutually Supportive and Reinforcing Trade and Climate Regimes," January 2016, available online at: http://www3.weforum.org/docs/E15/WEF_Climate_Change_POP.pdf.

[16] For detail on the indexes see Oregon Department of Environmental Quality, "Consumption-based Greenhouse Gas Emissions Inventory for Oregon," available online at: https://www.oregon.gov/DEQ/mm/Pages/Consumption-

My assessment of the UK and Oregon models reveals that neither system collects the data needed to move beyond sectoral averages. Further, neither system offers a vision for how such data could be collected and audited to check for data quality. With substantial cooperation across different jurisdictions, the necessary data infrastructure could be built, but doing so will take time and will require engaged international coordination, because building these systems without the cooperation of governments in exporting countries would set the system up for failure. In my view, unilateral action by the U.S. is insufficient to achieve this goal. My opinion is supported by assertions made by Stiglitz in his Expert Report, wherein he relies on standard economic theory to emphasize the need to "charge" emitters "…for the negative externalities they create, such as carbon emissions," but also recognizes that "…the vast majority of negative-externality carbon emissions across the globe are not priced." (page 38). Addressing this issue requires international engagement, such that any sovereign imposing emissions controls on produced goods also imposes a similar burden on its international trading partners with respect to the emissions associated with imported goods. It is my expert opinion that failure to engage with the international community on this issue will result in a flawed consumption-based accounting system that fails to effectively create the incentives needed for global action. Worse, poorly implemented consumption-based accounting systems and border adjustments could trigger retaliation and trade wars, if exporting countries feel their products are being unfairly targeted or importing countries feel they are at an economic disadvantage. Those side-effects of shifts in trade-related policies could compromise U.S. policy to preserve a free and fair system for trading goods and services in global markets.

In his Expert Report, Erickson also claims that "U.S. emissions from a consumption-based perspective have been higher than territorial emissions since about the mid-1980s, as growth in U.S. consumption of goods has outpaced growth in manufacturing." (page 9) However, Erickson fails to articulate how this proportional increase actually affects the U.S. overall share of global emissions. My assessment of the data reveals that a shift to consumption-based accounting affected the US share of global emissions by only about 1%. I show the data and method underpinning this calculation below.

In the early 1990s, the U.S. was a net exporter of emissions to other countries. Since 1990, the share of heavy manufacturing has declined, and the U.S. has become a net importer of emissions. The effect of this shift is shown in Figure 3 (Peters et al., 2011). I rely on Figure 3 as the basis of my opinion for two reasons. First, it is consistent with the method and data used in the first authoritative study based on consumption accounting. Second, it offers country-level data that is sufficiently transparent to be able to assess the numerical effects of consumption-based accounting systems.[17] According to the data in this study, the U.S. was a net importer of about

based-GHG.aspx, and Oregon Department of Environmental Quality, "Greenhouse Gas Emissions and Emissions Intensities for Consumption of Materials, Services, Fuels and Electricity," October 13, 2011, available online at: https://www.oregon.gov/deq/FilterDocs/wprSupTechRepGHGInten.pdf.

[17] See: (1) GP Peters and EG Hertwich, "CO2 Embodied in international trade with implications for global climate policy," *Environmental Science & Technology*, 42(5):1401-7, Mar 1, 2008; (2) Edgar G. Hertwich and Glen P. Peters, "Carbon Footprint of Nations: A Global, Trade-Linked Analysis," *Environmental Science & Technology,* 43(16):6414-6420, June 15, 2009. These two papers offer foundations for the Peters et al. 2001 analysis. The papers, along with the Peters et al 2011 paper, have been cited substantially in the academic community (approx., 3,000 times per Google Scholar). See also Steven Davis and Ken Caldeira, "Consumption-Based Accounting of $CO_2$ Emissions," *Proceedings of the National Academy of Sciences of the United States of America (PNAS)* March 2010

480 million metric tons of $CO_2$ emissions annually in 2008. That is, if the U.S. adopted a consumption-based accounting system, using the methods outlined in the Peters et al., 2011 study, U.S. emissions would have been about 480 million metric tons higher than U.S. emissions accrued under a territorial-based accounting system.[18] For comparison, that 480 million metric tons is about 8.6% of US total industrial $CO_2$ emissions in 2008 using territorial accounting.[19]

Thus, if the U.S. had adopted a consumption-based accounting system, such as the kind of system advocated by Erickson's report, its emissions would rise about 8.6% above those accrued under the territorial-based accounting system. Applying this 8.6% increase to the most recent estimates for the US share of world emissions would raise the US share from 12% with territorial accounting to 13% with consumption-based accounting, i.e., an increase in the overall global share of U.S. emissions of 1%.[20] Concurrently, a shift from territorial-based to consumption-based accounting systems likely would lower China's responsibility for emissions by about three

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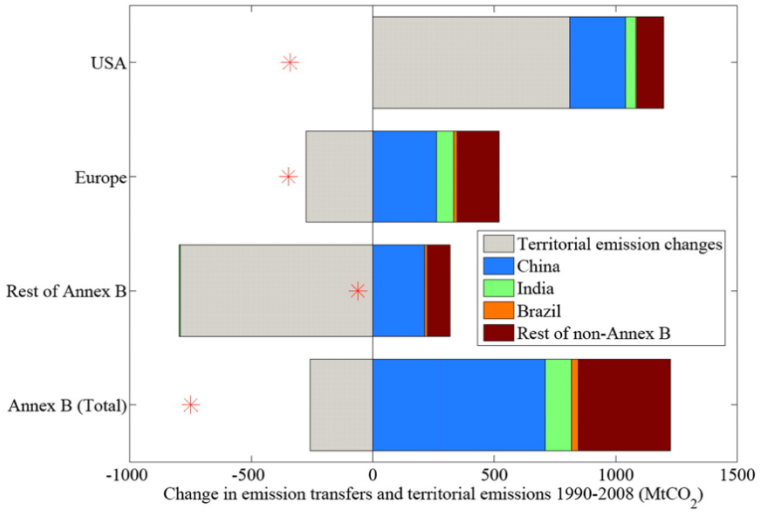
107(12):5687-92 (cited 1100 times). In addition, in his Expert Report, Erickson references four other studies that offer distinct methods and analysis:
A) John Barrett et al., "Consumption-Based GHG Emission Accounting: A Case Study," *Climate Policy* 13, no. 4 (July 1, 2013): 451 70.
B) Manfred Lenzen et al., "Building EORA: A Global Multi-Region Input Output Database at High Country and Sector Resolution," *Economic Systems Research* 25, no. 1(March 1, 2013): 20-49.
C) Peter Erickson, et al., "A Consumption_Based GHG Inventory for the U.S. State of Oregon," *Environmental Science & Technology*, 46(7):3679-3686, March 22, 2012.
D) Kirsten S. Wiebe and Norihiko Yamano, "Estimating CO2 Emissions Embodied in Final Demand and Trade Using the OECD ICIO 2015," OECD Science, Technology and Industry Working Papers (Paris: Organisation for Economic Cooperation and Development, September 3, 2016), available online at: http://www.oecd-ilibrary.org/content/workingpaper/5jlrcm216xkl-en.
These other four, measured by number of citations, have had a smaller impact on analytical research about consumption based accounting, with citations of 184, 505, 37, and 17 times (per Google Scholar). This citation analysis forms the basis for my choice of the Peters et al analysis to illustrate and elaborate my opinions in this Expert Report. This exercise is not intended to be a full assessment of the intellectual mapping of which groups and papers have had particular influence on the development of methods and analysis in this area. In my view, because the methods under development are at an early stage, and there are many different approaches and assumptions that could be applied, it is important to offer logic for why a particular study or method is used for a particular calculation.

[18] This number reflects the change in average U.S. emissions in 2008 between territorial-based accounting and consumption based accounting, as reported in Peters et al., 2011. Specifically, Dataset S1 to Peters et al. 2011, Worksheet "7.TSTRD_Transfers" Cell U36, indicates a 2008 "transfer," or difference between territorial- and consumption-based accounting systems of an increase of 479 million metric tons of $CO_2$ emissions.

[19] This figure computed by dividing 479 million metric tons into the estimated US industrial $CO_2$ emissions are reported in the EDGAR data sources for Figure 2 of my Expert Report (5,602 million metric tons in 2008). Other sources produce similar numbers, including official US Government data: U.S. Department of Energy, Energy Information Administration, Table 12.1 Carbon Dioxide Emissions From Energy Consumption by Source, https://www.eia.gov/totalenergy/data/browser/index.php?tbl=T12.01#/?f=A&start=1973&end=2017&charted=0-1-13. These data indicate 2008 "total energy $CO_2$ emissions" of 5,815 million metric tons.

[20] This calculation requires two proportionality assumptions that underscore why it would be valuable to have reliable time-series estimates for consumption-based emissions for all GHGs, and until those estimates exist the assumption of proportionality is the best approach for calculation. I assume that the effect of 8.6% is proportional to all GHGs and that the effect of shifting to consumption based accounting for the US in 2012 would be proportional to 2008.

464 times the increase in emissions attributable to the U.S.[21] This shift is attributable to the fact that,
465 since the early 1990s, the main pattern in global trade has been the rise of China as a net
466 exporter, and the rise of the U.S. and Western Europe as net importers of most of China's
467 emissions embodied in the country's exports.
468




469
470 *Figure 3: Shift in emissions (million metric tons of $CO_2$) from 1990 to 2008 due to a shift from*
471 *territorial to consumption-based accounting. The top bar of the figure shows the rise in US*
472 *territorial emissions (grey bars) over time period of concern plus the incremental increase due to*
473 *emissions caused by products that are imported to the U.S. from China (blue bar), India (green*
474 *bar) and other developing countries. Source: Peters et al PNAS (2011, Figure 3).*
475
476 **Finding #3. US FEDERAL ENERGY SUBSIDIES HAVE A SMALL AND DECLINING**
477 **IMPACT ON US TERRITORIAL ENERGY PRODUCTION**
478
479 When discussing U.S. subsidies, Erickson focuses predominantly on domestic fossil fuel
480 production, suggesting that U.S. subsidization of energy is dominated by fossil fuels. (page 13)
481 Notably, in Table 2 of his Expert Report, Erickson summarizes fossil fuel-related, direct
482 subsidies compiled by the US for the Group of Twenty (G20). (page 14) Erickson relies on the
483 data presented in Table 2 to highlight the magnitude of the spend made by the U.S. to subsidize
484 the fossil fuel infrastructure and production. In my expert opinion, Erickson's use and summary
485 of these data misleads the reader in two ways.
486

[21] See Dataset S1 to Peters et al 2011, Worksheet "7. TSTRD Transfers" Cells U36 and U52. China's estimated difference in 2008 between the territorial- and consumption-based accounting systems yields a decrease of 1,329 million metric tons of $CO_2$ (Cell U52); the corresponding difference for the United States is 479 million metric tons (Cell U36). 1,329 / 479 = 2.77, i.e., China's decrease in emissions from shifting from a territorial-based to a consumption-based accounting system is approximately three times as large as the United States' increase from this shift. Other authoritative studies lead to similar conclusions, but, as befits research projects where the underlying data about emission factors and trade patterns are contested, there remains uncertainty. For example, Davis and Caldeira 2010 report net imports of emissions into the United States from overseas (exclusive of intermediate goods) at about 600 million metric tons of $CO_2$ per year.

First, it is important to put the total subsidy spend into perspective. Using the same numbers quoted by Erickson ($4.8b of subsidy in 2015, mainly for oil and gas (page 13)), the total market value of oil produced in the U.S. in 2015 was about $172b,[22] and the value of produced natural gas was about $73b.[23] In total, US oil and gas producers extract commodities worth $245b per year. The subsidy embodied in the output is only about 1.9% of the total market value of production.[24] In my view, subsidies worth that tiny fraction of the total value are not material to an industry whose prices can swing many multiples of this percentage in a financial quarter.

Second, total energy subsidies include all forms of energy, not just fossil fuels, as suggested by the focus placed by Erickson in Table 2 of his Expert Report. Total subsidies are much larger and more nuanced than the simple direct expenditures summarized in Table 2.[25] In my opinion, by focusing on fossil fuel subsidies reported to the G20, Erickson cherry-picks just one element of the total subsidies picture. The data reported to the G20 was part of a policy exercise specifically focused on fossil fuel subsidies. In so doing, Erickson ignores the richer array of evidence that provides a complete picture of subsidies across the energy sector. Similarly, in his Expert Report, Stiglitz misleads the reader by focusing on fossil fuel subsidies, not acknowledging the full array of energy subsidies, and ignoring the shift in U.S. subsidy strategy away from fossil fuels and toward renewables. For example, Stiglitz asserts:

> "…for at least 40 years…direct and indirect subsidies to fossil fuel producers hinder thea doption of renewable energy and improvements in renewable energy technologies." (page 38-39)

As the basis for this assertion, Stiglitz cites an attachment to a 1978 memo from Jim Schlesinger to President Carter. Stiglitz offers no citations either to current retrospective analysis, (e.g., a

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[22] This is the simple volumetric calculation that multiples US. output for 2015 (9.4 million barrels per day, per U.S. Department of Energy, Energy Information Administration, U.S. Field Production of Crude Oil, 2015 at 9,408 thousand barrels per day, available online at: https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=mcrfpus2&f=a)) by approximate average price for the year ($50/bbl—slightly higher than West Texas Intermediate (WTI) at $49/barrel and slightly lower than Brent at $52/barrel, per U.S. Department of Energy, Energy Information Administration, "Crude oil prices started 2015 relatively low, ended the year lower," January 6, 2016, available online at: https://www.eia.gov/todayinenergy/detail.php?id=24432). 9,408,000 x 365 x $50 = $171,696,000,000, or approximately $172 billion.

[23] Calculated based on U.S. gas production of 79 billion cubic feet (bcf) per day (U.S. Department of Energy, Energy Information Administration, "U.S. natural gas production reaches record high in 2015," April 15, 2016, available online at: https://www.eia.gov/todayinenergy/detail.php?id=25832 ) and a wholesale Henry Hub price averaging $2.61 per million British thermal unit (MBBtu) that year (U.S. Department of Energy, Energy Information Administration, "Average annual natural gas spot price in 2015 was at lowest level since 1999," January 5, 2016, available online at: https://www.eia.gov/todayinenergy/detail.php?id=24412 ). 79 bcf is equal to 76.3 trillion BTU (conversion factor 0.966), or simply 76,300,000 million BTU. 76.3 x 365 x $2.61 = $72.687 billion, or approximately $73 billion.

[24] $4.8 billion divided by $245 billion yields approximately 0.02.

[25] The U.S. Department of Energy, Energy Information Administration, provides an array of studies that assess the state of governmental financial interventions and subsidies relevant to energy markets. See U.S. Department of Energy, Energy Information Administration, "Direct Federal Financial Interventions and Subsidies in Energy in Fiscal Year 2015," March 12, 2015, available online at: https://www.eia.gov/analysis/requests/subsidy/dmeess.php.

time series analysis of subsidy reform), or to relevant policy and analytical research on renewables and energy efficiency subsidies. Since 1978 a lot has happened, notably in shifting direct subsidies away from fossil fuels and toward renewables and energy efficiency. He notes, approvingly, that the price of solar panels is dropping (page 28). However, Stiglitz does not indicate that those declines are, in part, due to the direct subsidies that the U. S., Germany, China and other countries have offered and continue to offer to producers as well as purchasers of renewable energy equipment, along with a host of other reforms that have made it easier to connect solar electricity supplies to the grid. Instead, Stiglitz offers a hypothetical thought experiment as to the kind of redress that is appropriate without any foundational basis:

> "If Defendants stopped providing subsidies and/or implemented carbon pricing policies that allow the U.S. government to further fund research and development of green technologies to decarbonize the economy, such measures would have a large positive impact in the long term…" (page 39)

In my opinion, if Erickson or Stiglitz were to analyze the breadth of U.S. subsidies, they would concede a different perspective of U.S. policy with respect to subsidy and preferential treatment of renewables vis-à-vis fossil fuels. Challenges exist in conducting a meta analysis of this sort. Determining what constitutes a subsidy can be difficult, and accessing the relevant data necessitates engaging with many sections of the federal government. Mindful of these challenges, I elect to rely on the most recent (2012) systematic analysis by the Congressional Budget Office (CBO), which compiled a wide array of direct subsidies by energy source.[26] I choose to focus on direct subsidies, because the quantitative information in Erickson's Expert Report focuses on a selection of direct subsidies related to the production of fossil fuels.

A key finding from the CBO analysis is that tax-based subsidies dominate total federal support for energy sources. The CBO is systematic in their analysis of tax-based subsidies, which helps to frame the tax treatment of fossil fuels; starting with this kind of systematic analysis lowers the risk that statistics will be cherry-picked to favor one particular finding. As I previously stated, fossil fuels dominate Erickson's analysis of subsidies, particularly with respect to Table 2 of Expert Report.[27] Figure 4, below, reproduces the CBO's key findings with respect to tax-based subsidies.

[26] U.S. Congressional Budget Office, "Federal Financial Support for the development and Production of Fuels and Energy Technologies," Issue Brief, March 2012, available online at: https://www.cbo.gov/sites/default/files/112th-congress-2011-2012/reports/03-06-fuelsandenergybrief.pdf. In addition, the Congressional Research Service and the Office of Management and Budget have completed cross-sectoral studies of U.S. energy subsidies.

[27] The accounting methods used in U.S. Government, "United States Self-Review of Fossil Fuel Subsidies" (Submitted December 2015 to the G-20 Peer Reviewers, December 2015), http://www.oecd.org/site/tadffss/publication/, which informs Table 2 of Erickson's Expert Report differ from those used in the CBO's analysis. For a more detailed comparison, contrast Table 2 of Erickson's Expert Report with Table 1 in U.S. Congressional Budget Office, "Federal Financial Support for the development and Production of Fuels and Energy Technologies," Issue Brief, March 2012, available online at: https://www.cbo.gov/sites/default/files/112th-congress-2011-2012/reports/03-06-fuelsandenergybrief.pdf.

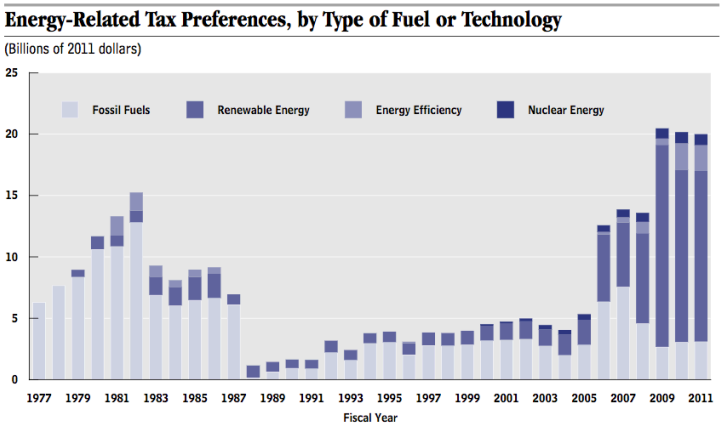


*Figure 4: Energy-Related Tax Subsidies, by Type of Fuel or Technology (billions 2011 USD). Figure reports data from 1977 through 2011, the time period of concern in the CBO study*[28].

Although the data captured by the CBO study is through 2011, and the data relied upon by Erickson from the G20 study is through 2015, a clear message emerges. While the CBO analysis is systematic, the Erickson analysis relies on cherry-picked subsidy statistics that focus on fossil energy subsidies, belying the larger picture. As the CBO study makes clear, most of the direct subsidy spend by the US on energy (as computed through tax preferences) is focused on renewables, not fossil fuels. Specifically, according to the CBO study, the portion of 2011 tax preferences (subsidies) attributable to fossil fuels is about $2.5b.[29] Whereas, the portion attributable to renewables is about $12.9b; wherein $6.9b is attributable to biofuels (ethanol and biodiesel), and the remaining $6b is attributable to other renewable power sources, such as solar and wind.[30]

In my opinion, it is instructive to normalize these amounts of tax-based subsidies according to production of fuels. As a fraction of the total U.S. energy supply, in 2011, fossil fuels accounted

[28] Source: U.S. Congressional Budget Office, "Federal Financial Support for the development and Production of Fuels and Energy Technologies," Issue Brief, March 2012, available online at: https://www.cbo.gov/sites/default/files/112th-congress-2011-2012/reports/03-06-fuelsandenergybrief.pdf, based on data from Molly F. Sherlock, Energy Tax Policy: Historical Perspectives on and Current Status of Energy Tax Expenditures, CRS Report for Congress R41227 (Congressional Research Service, May 2, 2011), p. 26; Joint Committee on Taxation, Estimates of Federal Tax Expenditures for Fiscal Years 2011-2015 (JCS-1-12, January 17, 2012)pp. 33-35; Office of Management and Budget, Budget of the U.S. Government, Fiscal Year 2013: Appendix (Feb 2012), p. 1068.

[29] U.S. Congressional Budget Office, "Federal Financial Support for the development and Production of Fuels and Energy Technologies," Issue Brief, March 2012, available online at: https://www.cbo.gov/sites/default/files/112th-congress-2011-2012/reports/03-06-fuelsandenergybrief.pdf. Within Table 1 (p. 3), the tax preferences for fossil fuels sum to $2.5 billion, or $0.8 billion + $0.8 billion + $0.9 billion

[30] U.S. Congressional Budget Office, "Federal Financial Support for the development and Production of Fuels and Energy Technologies," Issue Brief, March 2012, available online at: https://www.cbo.gov/sites/default/files/112th-congress-2011-2012/reports/03-06-fuelsandenergybrief.pdf. Within Table 1 (p. 3), the tax preferences for renewable energy sum to $12.9 billion ($1.4 + $0.7 + $6.1 + $0.8 + $3.9).

562 for 78% of total U.S. primary energy supply and received 12% in tax-based subsidies.[31,32] In
563 2011, new renewable energy technologies including wind, solar and biomass s accounted for
564 7.8% of U.S. primary energy supply and received 63% in tax-based subsidies. The numbers for
565 renewables are distorted by U.S. biofuels policy.[33,34] Nonetheless, my assessment reveals that
566 proportional to U.S. energy output, the tax-related subsidy for new renewables, in 2011, was
567 over 50 times the level of tax-related subsidies for fossil fuels.[35] This assessment reveals that,
568 when properly analyzed, U.S. subsidies have shifted, and continue to shift, in the direction of
569 energy sources that require market support, and are favored as contributing elements of a
570 diversified energy portfolio.
571

[31] U.S. Department of Energy, Energy Information Administration, Table 1.2 Primary Energy Production by Source, available online at: https://www.eia.gov/totalenergy/data/browser/index.php?tbl=T01.02#/?f=A&start=1949&end=2017&charted=1-2-3-4-6-13. Data indicate that total fossil fuel-based energy production in 2011 was 60.543191 quadrillion Btu, compared to 78.035874 total energy production, or approximately 77.58 percent.

[32] U.S. Congressional Budget Office, "Federal Financial Support for the development and Production of Fuels and Energy Technologies," Issue Brief, March 2012, available online at: https://www.cbo.gov/sites/default/files/112th-congress-2011-2012/reports/03-06-fuelsandenergybrief.pdf. Within Table 1 (p. 3), the tax preferences for fossil fuels sum to $2.5 billion, or $0.8 billion + $0.8 billion + $0.9 billion. $2.5 billion divided by total 2011 energy-related tax preference as reported in Table 1, or $20.5 billion, yields 0.122, or approximately 12 percent.

[33] U.S. Department of Energy, Energy Information Administration, Table 1.2 Primary Energy Production by Source, available online at: https://www.eia.gov/totalenergy/data/browser/index.php?tbl=T01.02#/?f=A&start=1949&end=2017&charted=1-2-3-4-6-13. Data indicate that total renewables-based energy production in 2011 was 9.223985 quadrillion Btu; of that total 3.102852 quadrillion BTU equivalents came from hydroelectricity. I exclude hydroelectricity from my calculation of the "renewables" subsidy share, because: (a) there is relatively little tax preference allocated to hydro, and (b) most studies about the potential for shifting to renewable energy (and the need for policy supporting that shift) focus on what are often called "new renewables," which is a concept that explicitly excludes the large hydro plants that account for nearly all US hydroelectricity production. That leaves 6.121133 quadrillion BTU of renewables output, compared to 78.035874 total energy production, or approximately 7.84 percent. The data available do not support disentanglig the federal tax preferences for hydroelectricity that might be included in the CBO analysis.

[34] U.S. Congressional Budget Office, "Federal Financial Support for the development and Production of Fuels and Energy Technologies," Issue Brief, March 2012, available online at: https://www.cbo.gov/sites/default/files/112th-congress-2011-2012/reports/03-06-fuelsandenergybrief.pdf. Within Table 1 (p. 3), the tax preferences for renewables sum to $12.9 billion ($1.4 + $0.7 + $6.1 + $0.8 + $3.9). $12.9 billion divided by total 2011 energy-related tax preference as reported in Table 1, or $20.5 billion, yields 0.629, or approximately 63 percent.

[35] $2.5 billion in tax preference relative to 60.543191 quadrillion Btu of energy produced in 2011 yields approximately $0.041292835 billion in tax preference per quadrillion Btu of fossil fuel energy produced. $12.9 billion in tax preference to 6.122 quadrillion Btu of energy produced in 2011 yields approximately $2.107453 billion in tax preference per quadrillion Btu of renewables-based energy produced. $2.107453 / $0.041292385 = 51.04, or approximately a factor of 51. (If this calculation is performed to include hydroelectricity, then the result is a factor of approximately 34.)

**Finding #4. CHANGING FEDERAL SUBSIDIES ON OIL WILL HAVE MINIMAL IMPACT ON GLOBAL OIL PRICES, OIL CONSUMPTION AND EMISSIONS**

In his Expert Report, Erickson states:

> "… with prices at or near $50 per barrel, the U.S. government is substantially expanding the country's future oil production, relative to if these subsidies were not in place." (page 16)

Erickson concludes:

> "… it is my professional opinion that, at least for oil, Federal Government subsidies are likely to both increase oil industry profits and increase U.S. oil production. Both of these outcomes make it more difficult for the U.S. to transition to a low-carbon economy and meet domestic and international climate goals …" (page 16)

In his Expert Report, Stiglitz echoes these views as part of a broader claim that the U.S. is engaged in a "perpetuation of a national fossil-fuel based energy system." (page 7) Stiglitz fails to provide a well-founded basis for this opinion. I focus on the assertions made by Erickson regarding the impact of subsidies on oil production, because they are quantitative and based on a model analysis, for which the underlying assumptions about the factors that affect production can be scrutinized and compared with the literature.

In my view, Erickson has selectively targeted data and tailored his methods to inflate the beneficial impacts of subsidy reform on U.S. consumption of fossil fuels, and associated reductions in emissions contributions. My assessment of Erickson's research indicates that Erickson mines the facts to support his arguments about the impact of subsidies on oil production. Specifically, Erickson is conspicuously silent about the range of expert views on the matter of subsidy reform in the oil sector. Erickson limits the bases of his opinions to illustrative calculations from one set of studies (for which Erickson is co-author). Yet other reputable studies, including studies that Erickson himself cites, point to different conclusions. Based on my examination of these other studies, I conclude that the effect of oil subsidy reforms on emissions will be much smaller than suggested by Erickson, because other factors have a much larger impact on production decisions, the industry is highly competitive and responsive to changes in market conditions and production costs. In addition, relative to the size of the sector, the impact on the total financial picture of the industry is extremely small (on the order of 1% of turnover, as I describe below). Below, I detail the three bases for my conclusions.

First, Erickson's findings are based on a thought exercise that is not reflective of reality. Erickson's thought exercise is predicated on substantial changes to the U.S. tax code to remove all subsidies related to fossil fuels while leaving subsidies that affect the rest of the energy system untouched. Moreover, Erickson's Report is misleading, because he offers his opinions in the context of altering relatively narrow tax measures. Yet, to support his opinions he relies on a modeling study that actually adopts an expansive notion of subsidy, which includes topics such as liability transfers to the government for closure of oil wells, transfer of railroad safety risks to the public, public funding of the strategic petroleum reserve, public coverage of damage to roads,

and a host of other measures.[36] On page 14, Erickson presents Table 2, which lists direct subsidies for coal, oil and gas—subsidies that he calls "tax measures" (line 602). Then on page 15, Erickson points to other industry and academic studies that examine these "tax measures." As a means of further comparison, Erickson then turns to his own opinion, relying notably on a peer-reviewed 2017 publication in *Nature Energy*.[37] In fact, the modeling methods and data utilized in the *Nature Energy* paper are not limited to tax measures but rely on Erickson's more expansive notion of subsidies. Through this sleight of language in Erickson's Expert Report, the reader is left with the impression that, at oil prices of $50/barrel, as Erickson says of his team's analysis: "…we found that 47% of new U.S. oil investment would depend on subsidies to proceed." (page 15). This statement reports data from his Nature Energy paper[38] that, in fact, is based on model runs that assume his fully expansive view of subsidies. In his Expert Report, Erickson then returns to the narrow definition of tax measures, comments on the effect of intangible drilling costs (a tax measure), and draws the general conclusion: "…the U.S. government is substantially expanding the country's future oil production, relative to if these subsidies were not in place." (page 16). Erickson never explains (either in his Expert Report, or in the published materials that he cites) how much of the effect is due to tax measures and how much hinges on his more expansive notion of subsidies. As a result, the reader is left wondering how the scope of Erickson's analysis compares with the assertions made in his Expert Report. For these reasons, I believe that Erickson's assertions on these matters are unsupported and unreliable.

For Erickson's thought exercise to be successful, expansive changes would be needed not just in federal policy, but also to state tax codes and local zoning ordinances associated with infrastructure improvements. If there were substantial changes in federal policy then states and localities also would respond, often with counter-acting effects. Yet, in his Expert Report, Erickson is silent on the breadth of policy intervention that his thought exercise would necessitate and also silent on possible counter-vailing responses. It is only upon examination of the underlying technical documentation that informs Erickson's analysis that the breadth of intervention becomes clear.[39] Further, it is only upon examination of the underlying fundamentals of Erickson's analysis that one understands the degree to which Erickson's findings rely on unilateral or binary assumptions—if all subsidies were removed, then a preferred outcome arises. Common sense dictates that policy intervention involves various slopes (or

[36] See table 1 of P. Erickson, A. Down, M. Lazarus, D. Koplow, "Effect of subsidies to fossil fuel companies on United States crude oil production," Nature Energy 2:891-898 (2017) And for more detail see supplemental materials to that article at Supplementary information is available for this paper at https://doi.org/10.1038/. s41560-017-0009-8.

[37] P. Erickson, A. Down, M. Lazarus, D. Koplow, "Effect of subsidies to fossil fuel companies on United States crude oil production," Nature Energy 2:891-898 (2017)

[38] See table 2 of P. Erickson, A. Down, M. Lazarus, D. Koplow, "Effect of subsidies to fossil fuel companies on United States crude oil production," Nature Energy 2:891-898 (2017)

[39] In particular, the appendix to the 2017 Working Paper that offers more detail on See P. Erickson, A. Down, M. Lazarus, D. Koplow. Effect of government subsidies for upstream oil infrastructure on U.S. oil production and global CO2 emissions. 2017. Stockholm Environment Institute Working Paper 2017-02. I rely on that working paper because it offers a fuller assessment of the modeling work and how it compares with other studies than is available in the supplemental materials to the published peer-reviewed article from the same study team, which are available at: https://doi.org/10.1038/. s41560-017-0009-8.

degrees) of change. In his expert report, Erickson does not contemplate, or analyze the impact of, degrees of change arising from his proposed policy intervention(s).

Second, Erickson frames the basis for his argument in general terms of supply and demand and points to other industry and academic studies that, he implies, offer supportive conclusions. For example, he begins his comparison of other studies with the statement "[t]here is evidence that these tax measures positively affect fossil fuel industry profits and investment…" (page 14) Perhaps this is a fair statement, because it is so general; but the details can have a large impact on the conclusions. My examination of the existing literature suggests that the existing literature nuanced. Reasonable disagreement exists as to whether subsidy reform would have a material impact on U.S. oil production.

Before presenting his results, Erickson points to two others studies that have examined how tax-based subsidies might affect behavior in the industry. Other materials published by Erickson and his co-authors allow some detailed comparison between his opinion and these two published studies.[40] My analysis of these comparisons suggests that the differences across the studies are large. Notably, I believe that this is something that Erickson has found in his own published research, yet he elects to not mention or explain these differences in his Expert Report. The first study was completed by Dr. Gilbert Metcalf, a highly respected economist; the second study was completed by Wood Mackenzie, a highly respected energy research and consultancy group.[41]

The study completed by Metcalf has the benefit of being straightforward. Specifically, at prevailing oil prices of $50/bbl, Erickson's studies suggest that 72% of the onshore projects by independent oil producers depend on the presence of subsidies,[42] whereas Metcalf concludes that just 8% of the onshore independent producers on subsidy for their decision to drill.[43] Offshore,

[40] P. Erickson, A. Down, M. Lazarus, D. Koplow. Effect of government subsidies for upstream oil infrastructure on U.S. oil production and global CO2 emissions. 2017. Stockholm Environment Institute Working Paper 2017-02.

[41] These comparisons are referenced in the appendices (Tables A-5 and A-6) to a working paper that Erickson cites as technical support for the oil market model, and which he uses as the basis for his Expert Report. See See P. Erickson, A. Down, M. Lazarus, D. Koplow. Effect of government subsidies for upstream oil infrastructure on U.S. oil production and global CO2 emissions. 2017. Stockholm Environment Institute Working Paper 2017-02.

[42] See P. Erickson, A. Down, M. Lazarus, D. Koplow. Effect of government subsidies for upstream oil infrastructure on U.S. oil production and global CO2 emissions. 2017. Stockholm Environment Institute Working Paper 2017-02., Table A-5, p. 47. See also P. Erickson, A. Down, M. Lazarus, D. Koplow, "Effect of subsidies to fossil fuel companies on United States crude oil production," Nature Energy 2:891-898 (2017)

[43] Gilbert E. Metcalf, "The Impact of Removing Tax Preferences for U.S. Oil and natural Gas Production: Measuring Tax Subsidies by an Equivalent Price Impact Approach," NBER Working Paper Series, NBER, August 2016, available online at: http://www.nber.org/papers/w22537.pdf. See Table 5, p. 40, which indicates that the change in drilling rates for independent on shore oil producers is an 8.2 decrease (given an absence of subsidy). For consistency I will cite the NBER version of the paper because that is what Erickson cited, but the more authoritative version is peer-reviewed and published: Gilbert E. Metcalf. "The Impact of Removing Tax Preferences for U.S. Oil and Gas Production" *Journal of the Association of Environmental and Resource Economists* Vol. 5 Iss. 1 (2017) p. 1 – 37. Doi: 10.1086/693367

the differences are even larger. Specifically, according to Erickson's research, 100% of independent offshore drilling depends on subsidy,[44] whereas Metcalf concludes that just 17% of independent offshore drilling depends on subsidy.[45]

Erickson's Expert Report suggests that his findings are consistent with "university and research studies" (page 15), wherein he specifically cites to the Metcalf study (page 15, FN 33). However, as per the parameters summarized above, my assessment of the Metcalf analysis suggests a conclusion that is opposite to that proffered by Erickson. Specifically, at least for oil, the Metcalf study suggests that Federal government subsidies have little impact on U.S. oil production because most of the types of wells drilled for new production (onshore and offshore) are profitable without subsidies.

In addition, Erickson cites three times to a policy brief by Joe Aldy, implying a further consistency between his opinion and that of other experts. (Aldy is an economist—formerly in the U.S. Government and now at Harvard's Kennedy School.) My examination of the Aldy brief suggests that, in fact, it is not consistent with Erickson's position. Specifically, Aldy concludes that oil production subsidies "have a very small impact on production, their removal will not materially increase retail fuel prices, reduce employment, or weaken U.S. energy security."[46]

With regard to the study completed by Wood Mackenzie, which Erickson discussed only in passing in his Expert Report, the key question of concern is whether preferential tax treatment associated with Intangible Drilling Costs (IDC) has a material impact on oil production, prices, oil consumption, and by extension emissions contribution. The oil industry is attentive to IDC, because it is the largest single subsidy for oil and gas production. In Erickson's own study published in *Nature Energy*, he and his co-authors also find that IDC has the single largest impact on the IRR that they estimate for new drilling.[47] For example, in 2015, it accounted for

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[44] See P. Erickson, A. Down, M. Lazarus, D. Koplow. Effect of government subsidies for upstream oil infrastructure on U.S. oil production and global CO2 emissions. 2017. Stockholm Environment Institute Working Paper 2017-02., Table A-5, p. 47, Table A-5, p. 47.

[45] Gilbert E. Metcalf, "The Impact of Removing Tax Preferences for U.S. Oil and natural Gas Production: Measuring Tax Subsidies by an Equivalent Price Impact Approach," NBER Working Paper Series, NBER, August 2016, available online at: http://www.nber.org/papers/w22537.pdf. See Table 5, p. 40, which indicates that the change in drilling rates for independent on shore oil producers is an 8.2 decrease (given an absence of subsidy). There are many differences between the models that can explain these results, not least of which is the fact that the Metcalf results are presented independent of price, whereas Erickson's team presents their own model with price-dependent results. The Metcalf study is presented in a working paper by an academic foreign policy think tank (The Council on Foreign Relations—I am a member of that organization), and the Erickson detailed studies are presented in a working paper by a think tank, with which he is affiliated (Stockholm Environment Institute). Neither of these working papers appears to be reviewed in the manner typical of academic journals, and neither author has been asked to do the detailed model-by-model comparisons that are typical in the energy modeling community.

[46] Joseph E. Aldy, "Report: Eliminating Fossil Fuel Subsidies," February 26, 2013, Proposal 5 in Brookings Institution, "15 Ways to Rethink the Federal Budget," published February 22, 2013, available online at: https://www.brookings.edu/research/eliminating-fossil-fuel-subsidies/.

[47] See the waterfall charts in figure 2 of P. Erickson, A. Down, M. Lazarus, D. Koplow, "Effect of subsidies to fossil fuel companies on United States crude oil production," Nature Energy 2:891-898 (2017),

$1.6b/yr in subsidy.[48] But this amount must be kept in perspective. As a measure of comparison, $1.6b/yr is 0.6% of the produced value of oil and gas in the U.S.[49]

In my view, the issue of concern is not whether the oil industry would prefer to preserve a preferential tax treatment, but rather whether eliminating the preferential treatment (or subsidy) for IDC has a material impact on oil production. I discuss the particulars of this study by Wood Mackenzie, and its relevance to Erickson's opinion in more detail below.

First, Erickson's own research—published elsewhere, but not discussed in his Expert Report—reveals that the magnitude of effects in the Wood Mackenzie model differ from those in Erickson's model by a factor of two or more.[50] By citing the Wood Mackenzie model as a basis for his opinion, yet offering an opinion that deviates substantially from that study, Erickson confounds the question of the impact of subsidies on production. Given the breadth of uncertainty raised by the differences in subsidy effects analyzed in the Erickson, Metcalf, and Wood Mackenzie studies, the actual impacts of subsidies on oil production appear to be a matter of substantial debate. In my view, the degrees of difference between all three analysis reinforce that Erickson's opinion, as proffered in his Expert Report is unreliable.

Second, the scope of the Wood Mackenzie study is different than that of Erickson's research. Erickson is focused on oil production; oil is a highly marketable commodity, easily transported to market. By contrast, the Wood Mackenzie study examined the impact of IDC on oil *and* gas drilling activity. In general, the drilling costs associated with gas wells tend to be more sensitive to costs, and therefore more sensitive to changes in preferential tax treatment, because the price of gas remains low in the U.S. due to the technological advances associated with shale gas exploration. Erickson is silent on these significant methodological differences in approach between his analysis and the Wood Mackenzie study. Given these methodological differences, it is not self-evident that the Wood Mackenzie study supports Erickson's analysis. In my view, across the array of studies on which Erickson relies to form the basis of his opinion, there is no consensus on the effect of subsidies on oil production

In addition to Erickson's discussion regarding onshore drilling, which I find to be unsubstantiated and unreliable, the modeling studies that Erickson uses as a basis for his opinion include estimates that 73% of undeveloped offshore resources depend on subsidy to be economic at $50/bbl. In my view, this finding, and thus the opinions in Erickson's Report that are based in

[48] According to US Government estimates that are reprinted in Table 2 of Erickson's expert report.

[49] See discussion under Finding #3 of this report. Total market value of oil produced in the United States in 2015 was about $172b, and the value of produced natural gas in 2015 was about $72b. Therefore, $1.6 billion divided by ($172b + $72b) yields approximately 0.0065306, or 0.6 percent. Here I focus on oil and gas together because IDC applies to both, but Erickson's analysis looks only at oil.

[50] The Wood Mackenzie study finds that 40% of onshore projects depend on this subsidy, compared with Erickson's own research, suggesting that 18% of onshore projects have such dependency. Offshore, the results are reversed and even larger—9% for Wood Mackenzie and 25% for the Erickson team. See Wood Mackenzie, *Impacts of Delaying IDC Deductibility* (2014-2025), prepared for the American Petroleum Institute, 2013, available online at: http://www.api.org/~/media/files/policy/taxes/13-july/api-us-idc-delay-impacts-release-7-11-13.pdf and P. Erickson, A. Down, M. Lazarus, D. Koplow, "Effect of subsidies to fossil fuel companies on United States crude oil production," Nature Energy 2:891-898 (2017), Table A-6, p. 48.

part on this finding, also is unsubstantiated and unreliable. The study by Metcalf, which looked at this issue, offers no such support for that conclusion.[51] Nor does one find support in the real world. Prior to 2014, when oil prices were high, a coalition led by BP planned a $20b offshore oil production project in the Gulf of Mexico called "Mad Dog 2." Co-located near an existing oil field (Mad Dog 1), Mad Dog 2 would produce 140,000 barrels per day. When oil prices crashed in 2014, Mad Dog 2 was idled and redesigned using more standardized platform designs and a host of improvements that radically reduced costs. In December 2016, when oil prices were forecasted at $50/bbl, or about half the level prior to the price crash of 2014, BP restarted Mad Dog 2. In announcing the venture, BP's CEO stated: "This announcement shows that big deep water projects can still be economic in a low-price environment in the US if they are designed in a smart and cost-effective way."[52] Although these changes are under way in the real world, in Erickson's peer-reviewed *Nature Energy* paper, he and his co-authors exclude offshore drilling from the main display figure. They state: "…Very few projects for offshore Gulf of Mexico are economic at an oil price of US $50 per barrel, and the effect of subsidies is both small in IRR terms and highly variable."[53] Yet, it is precisely in that real-world context—oil at $50, and subsidies that have a small and variable effect on the internal rate of return (IRR) for offshore drilling, that BP restarted Mad Dog 2, arguably one of the largest new oil production projects in the Gulf of Mexico. This anecdote illustrates that the industry is accustomed to responding to changes in the fiscal environment for projects that are forecasted to yield returns irrespective of the contemplated elimination of direct subsidies.

In my opinion, tinkering at the margins of the fossil fuel sector with subsidy policy—even an extreme tinkering with Erickson's proposed realignment of the U.S. tax code—is dwarfed in relevance by market and technological forces. Direct production subsidies are on the scale of 1% of industry production; real technological and operational changes have responded to changes of 50% in the value of produced oil in just a few years. Further, the studies Erickson relies upon to support his arguments fail to evince a clear relationship between subsidy policy and oil production.

**Finding #5. CHANGING FEDERAL COAL LEASING POLICIES WILL HAVE SMALL EFFECTS ON US CONSUMPTION OF COAL AND EMISSIONS CONTRIBUTIONS**

In his Expert Report, Erickson states:

> "…federal land leasing practices show how the Federal Government plays a significant role in aiding and facilitating U.S. fossil fuel extraction" (page 19)

Essentially, Erickson asserts that the U.S. subsidizes fossil fuel extraction by leasing federal lands to industry actors, and failing to charge lessees the *full* cost of extraction from federal

[51] Gilbert E. Metcalf, "The Impact of Removing Tax Preferences for U.S. Oil and natural Gas Production: Measuring Tax Subsidies by an Equivalent Price Impact Approach," NBER Working Paper Series, NBER, August 2016, available online at: http://www.nber.org/papers/w22537.pdf.

[52] Jessica Tippee, "Re-engineered Mad Dog Phase 2 gets the greenlight," *Offshore*, January 2, 2018, available online at: https://www.offshore-mag.com/articles/print/volume-77/issue-12/top-offshore-projects/re-engineering-mad-dog-phase-2-gets-the-greenlight.html.

[53] See caption to figure 2 on page 894: P. Erickson, A. Down, M. Lazarus, D. Koplow, "Effect of subsidies to fossil fuel companies on United States crude oil production," Nature Energy 2:891-898 (2017)

776 lands. Erickson, in particular, focuses his analysis of leasing reform on coal. In his Expert
777 Report, Stiglitz offers supporting comments for coal leasing reforms that would charge producers
778 the full costs of extraction from federal lands, including charges for the harm caused by GHG
779 emissions (page 36); Stiglitz asserts that the U.S. should "cease approvals for any new fossil fuel
780 infrastructure." (page 39)
781
782 I examine the impacts of coal leasing reforms as asserted by Erickson in his Expert Report,
783 because this is the area where it is possible to compare Erickson's assertions with leasing reform
784 proposals that have been the subject of quantitative examination by other analysts. The issue at
785 hand is whether eliminating federal leasing practices for coal extraction would have a material
786 impact on the U.S. output of coal, the price of coal, and thus coal consumption and attendant
787 emissions contributions in the U.S. I believe that the research on this issue is nuanced and
788 largely unsupportive of Erickson's findings. I discuss the basis for my opinion below.
789
790 First, it is difficult to evaluate the data and methods used by Erickson, and therefore substantiate
791 his conclusions regarding federal leasing reform. Erickson does not offer a model-based analysis
792 as the basis for his views, nor does he offer the findings of an independent literature review.
793 Instead, Erickson appears to base his conclusion on the logic of supply and demand; he suggests
794 that leasing reforms will constrain supply, prices will then go up, and demand must go down.
795 He observes that the impact of leasing reforms on fuel prices and $CO_2$ emissions "depends on
796 one's view of how fuel markets operate" (page 18). Yet, Erickson's analysis includes no serious
797 attention to how the coal market actually functions. The users of coal (mainly electric utilities)
798 are under extensive regulatory and business pressures that affect the ultimate demand for coal.
799 Moreover, transportation costs are a larger share of delivered fuel prices. When transport is
800 expensive, changes in production costs have a smaller impact on the cost of delivered coal.
801 Further, even if major sources of fossil fuels from federal lands are curtailed—for example, if
802 coal extracted from federal lands were to become more expensive or curtailed altogether—then,
803 in a free market structure, other suppliers could potentially offset or erase the effects from federal
804 leasing reforms.
805
806 I agree with Erickson that an understanding of how markets operate is critically important; in
807 my view, the qualitative schematic that Erickson offers to explain behavior in the coal market is
808 not accurate. In my opinion, wholesale reform of federal fossil fuel leasing policies warrants
809 more rigorous analysis of attendant impacts than that presented by Erickson in his Expert Report.
810
811 Second, Erickson demonstrates lack of attention to the existing literature on the topic of federal
812 fossil fuel leasing reform. Similar to his discussion of subsidy reform, Erickson's Expert Report
813 suggests that academic research is supportive of his conclusions. As the basis for his opinion,
814 Erickson asserts there has been little analysis of the impact on emissions of constraints imposed
815 on U.S. fossil fuel production. In my opinion, this is incorrect. Erickson also posits that there is
816 widespread agreement regarding the effects of leasing reform fossil fuel markets. He cites to a
817 body of literature focused on the function of energy markets (ref 53 in the Erickson report); yet,
818 he does not elaborate on what those studies actually show. My examination of this literature, and
819 all the other literature that Erickson cites with regard to the coal market, reveals that, on balance,
820 the most reliable expert studies are not supportive of Erickson's position. My review of
821 Erickson's Expert Report reveals that, despite citing various bodies of literature in support of his
822 opinions, Erickson fails to acknowledge and rebut the areas of differences between the literature

cited and his findings. In fact, the studies cited by Erickson offer a more nuanced view of the impacts of coal leasing reforms than that asserted by Erickson in his Expert Report. Below, I discuss my assessment of two studies cited by Erickson

The first study cited in ref 53 of Erickson is a detailed model analysis by Gerarden et al., 2016. This study examines the coal leasing reforms that Erickson asserts should be adopted by the U.S. The Gerarden study reveals interactions that explain why federal leasing reforms have indirect and small impacts on emissions contributions.[54] Notably, the study reveals that only about 40% of US coal production comes from federal lands, and thus the impact of leasing reforms on total production requires modeling of the entire coal market—federal and non-federal sources. The study further cautions that any such modeling effort also must address the fact that higher prices on federal lands likely will be offset by new coal supplies arising from non-federal lands.[55] It is instructive to note that, since 2008, U.S. coal shipments to the electric power sector (by far the dominant user of coal in the country) have already declined 36%--an amount nearly equal to Gerarden et al.'s estimate of the entire production from federal lands.[56] Those declines are due principally to factors unrelated to coal leasing reform—such as inexpensive natural gas and larger mandates for (and greater economic competitiveness of) renewable energy[57]—and are indicative of the large excess supply of coal that stands ready to fill the market even if changes to federal coal leasing affected the supply and price of coal.

Other academic studies reveal complementary findings to those of Gerarden et al., 2016. For example, a study by the consultancy ICF looks at a large number of scenarios that include many interventions in the federal coal leasing program.[58] This study has the advantage that the model used allows calculation of the full array of energy sources used to generate electricity (known as the "generation mix"), and thus can examine the impact of coal leasing reforms on consumption of coal by the industry's largest customer (power utilities) and total emissions. Erickson cites this study to support the point that curtailment in federal coal leasing will lead to substitution of coal by less emission-intensive renewables or natural gas (page 19). In fact, the ICF study is much more nuanced and generally finds the opposite conclusion regarding the generation mix. That study concludes that the leasing reforms have little impact because "…increased production from non-federal coal offsets the reductions in federal coal, leaving national coal-fired

[54] Todd Gerarden, W. Spencer Reeder, and James H. Stock, "Federal Coal Program Reform, the Clean Power Plan, and the Interaction of Upstream and Downstream Climate Policies," NBER Working Paper No. 22214, issued April 2016, available online at: http://www.nber.org/papers/w22214. An assumption in this analysis is that coal buyers face other limits on the cost-effectiveness of coal purchases when compared with other fuels, such as natural gas. Gerarden et al., 2016 model those limits using the CPP, but any other set of similar constraints would have similar effects and lead to the same conclusion; that is, coal leasing reforms have minimal impact on coal production, consumption and emissions. Despite current policy discussions about repeal of the CPP, large coal-fired electric utilities (the main buyers of coal in the United States) are making investment and operational plans as if the CPP or other incentives, such as state-level policies, would continue to exist. Thus the Gerarden et al analysis remains germane to the real world effects of a potential coal leasing reform.

[55] Ibid.

[56] US Energy Information Administration. US Coal Shipments Reach Their Lowest Level in Years. 2018. https://www.eia.gov/todayinenergy/detail.php?id=36812

[57] K. Larsen, J. Larsen, W. Herndon, S. Mohan, and T. Houser, *Taking Stock 2017: Adjusting Expectations for US GHG Emissions* (Rhodium Group, 2017).

[58] Vulcan/ICF, "Federal Coal Leasing Reform Options: Effects on CO2 Emissions and Energy Markets, Summary of Modeling Results, Final Report" (Vulcan, Inc. report with analysis supported by ICF International, January 26, 2016)

generation unchanged." Yet Erickson concludes his assessment of coal leasing reforms with the statement that "any constraints on coal supply are expected to affect prices and lead to reduced coal consumption for power generation [and lower $CO_2$ emissions]." (page 19)

Erickson offers this conclusion despite the fact that, in the actual U.S. coal market, whether "any" constraint on supply affects demand depends on the actions of substitute suppliers and on factors that affect demand for coal. This is especially true in the electric power sector, where most coal is consumed in the U.S., and where coal competes directly with rival sources of power, such as renewables and natural gas . For example, Erickson cites a recent study by Houser et al., which explores whether coal can make a "comeback." This study is instructive, because it looks exactly at the kinds of policy scenarios that Erickson is considering. Specifically, Houser et al assess the effects of coal leasing reforms on the competitiveness of coal, and then assess outcomes assuming such policies were removed. Houser et al conclude that a shift in policy "could stem the recent decline in U.S. coal consumption, but only if natural gas prices increase going forward. If natural gas prices remain at or near current levels or renewable costs fall more quickly than expected, U.S. coal consumption will continue its decline."[59] I believe that current drilling behavior and technological advances in the gas market suggest that prices for natural gas will remain low for the foreseeable future.

In my opinion, irrespective of federal fossil fuel leasing reforms or reversal of preferential tax-based subsidies, it is probable that coal extraction will continue to decline over time, and attendant emissions contributions also will decline. I base this opinion on the breadth of my institutional expertise and assessment of the literature.

**Finding #6. THE U.S. DID NOT FAIL TO TAKE AN AFFIRMATIVE ACTION TO ELIMINATE FOSSIL FUELS AFTER THE ENERGY CRISES OF THE 1970S.**

In his Expert Report, Stiglitz asserts that, since the watershed moments of the 1970s, the U.S. has perpetuated a fossil energy system. Specifically, Stiglitz states:

> "The fact that the U.S. national energy system is so predominately fossil fuel-based is not an inevitable consequence of history. With the oil crises of the 1970s, recognition of the risks of dependence on oil was developed (though these risks were markedly different from those with which we are concerned today). Even then, it was clear that there were viable alternatives, and with the appropriate allocation of further resources to R&D, it is likely that these alternatives would have been even more competitive. Thus, the current level of dependence of our energy system on fossil fuels is a result of intentional actions taken by Defendants over many years (including subsidization of fossil fuels and inactions in the form of not providing adequate support for alternatives)." (page 12)

Stiglitz further states:

[59] Trevor Houser, Jason Bordoff, and Peter Marsters, Center on Global Energy Policy, "Can Coal Make a Comeback?" April 2017, available online at: http://energypolicy.columbia.edu/sites/default/files/Center%20on%20Global%20Energy%20Policy%20Can%20Coal%20Make%20a%20Comeback%20April%202017.pdf.

> "I would note that inactions in this sense are affirmative decisions by Defendants not to act." (page 12)

In my opinion, this assertion is not well-substantiated and is misleading. Stiglitz does not identify plausible, real-world actions that the U.S. could have taken that would have led to appreciably different outcomes. Contrary to what Stiglitz asserts, I believe that the dependence on fossil fuels which existed prior to oil crises of the 1970s, and which exists today, is the "inevitable consequence of history." (page 12) Two facts support my opinion.

First, every major industrial economy faced similar challenges during the energy crises of the 1970s, and each of these economies emerged from the crises with energy systems dominated by fossil fuels.[60] Although several of these economies invested in the leading renewable power system of the day—hydroelectric energy—each economy remained dependent on fossil fuels. Two of these large industrial economies—France and Japan—invested in nuclear power. In the case of France, which made the most decisive shift to nuclear power of any major economy, half of its energy system relies on fossil fuels and 41% relies on nuclear power.[61] In the case of Japan, nuclear power accounted for 15% of the country's energy system, and fossil fuels accounted for 80%.[62] Since 1998, the share of fossil fuels has increased. I cite to these examples to illustrate that the U.S. was not alone in its response to the energy challenges arising from the crises of 1970. Despite all this sustained attention the challenge of fossil fuel supply across the global economy and despite substantial spending on alternative energy systems, fossil fuels remained the dominant energy source for the global economy and all major industrial economies. In my expert opinion, as a historian of energy technology, I believe that the global race to dependence on fossil fuels, indeed, was inevitable. Further, my opinion is supported by internationally recognized historians in energy technology.[63]

Second, Stiglitz's assertion that dependence on fossil fuels was not an "inevitable consequence of history" is based on the premise that viable alternatives to fossil fuels were available, but for a failure of the Federal government to invest in associated research, development and demonstration of new technologies (RD&D). Stiglitz misrepresents the magnitude and breadth

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[60] The one possible exception to this statement is the Soviet Union, a large industrial economy that, at the time embraced central planning and had significant fossil fuel production of its own. It did not experience the energy crises of the 1970s in the same way. Nonetheless, the Soviet Union also maintained a fossil fuel-dominated energy system.

[61] These data computed from BP Statistical Review of World Energy, a widely used expert reference source, available online at: https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html. Data for France are for 2015, the peak year for nuclear since 1965 and thus the year when fossil fuels accounted for their smallest share of the French energy system. The French share of fossil energy declined below 70% for the first time in 1985 as the country's nuclear deployment program accelerated and has been below that level ever since.

[62] Ibid.

[63] .H. Ausubel, A. Grubel, and N. Nakicenovic, "Carbon Dioxide Emissions in a Methane Economy," *Climatic Change* 12:245 (1998). Vaclav Smil, *Energy at the Crossroads: Global Perspectives and Uncertanties* Cambridge: MIT Press, February 11, 2005.

of the Federal government's contributions to RD&D.[64] I have examined the data, and contrary to Stiglitz's assertion, the U.S. has devoted a substantial and growing fraction of its RD&D budget in the known alternatives to fossil fuels. Figure 5 shows public-sector energy-related spending (in constant dollars) on R&D by source. The data supports my conclusion that the U.S. substantially invested in zero-emission and low emissions technologies: nuclear power, renewables, and energy efficiency. When viewed holistically, since 1980, a greater proportion of public-sector spending has focused on non-fossil fuel related energy systems than on fossil fuels.

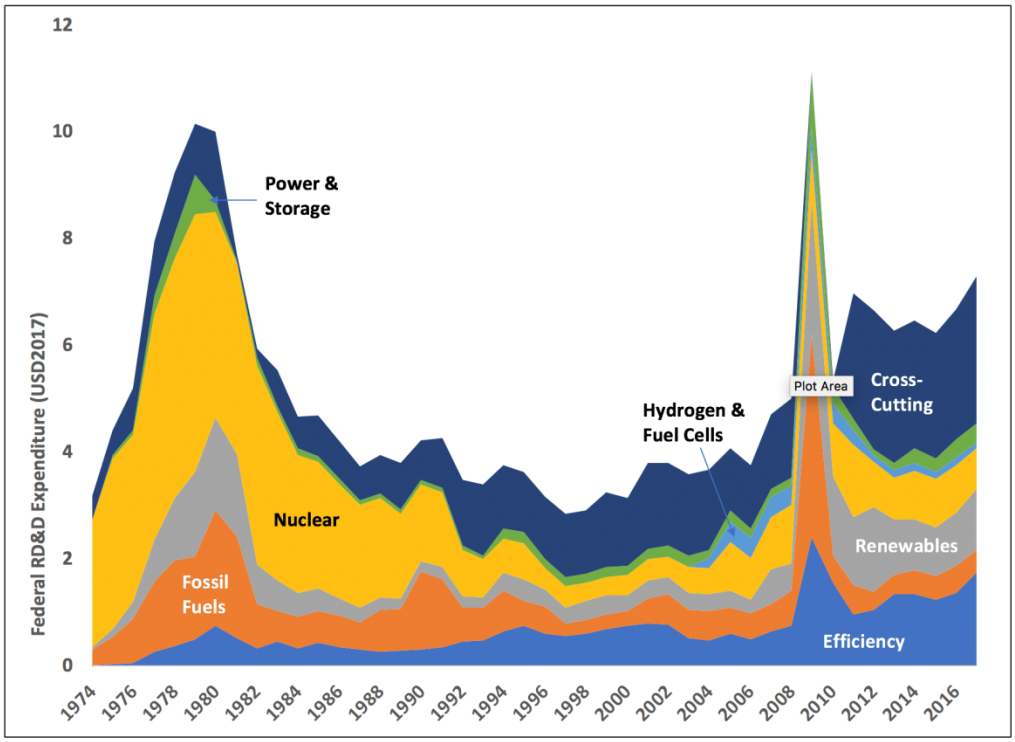


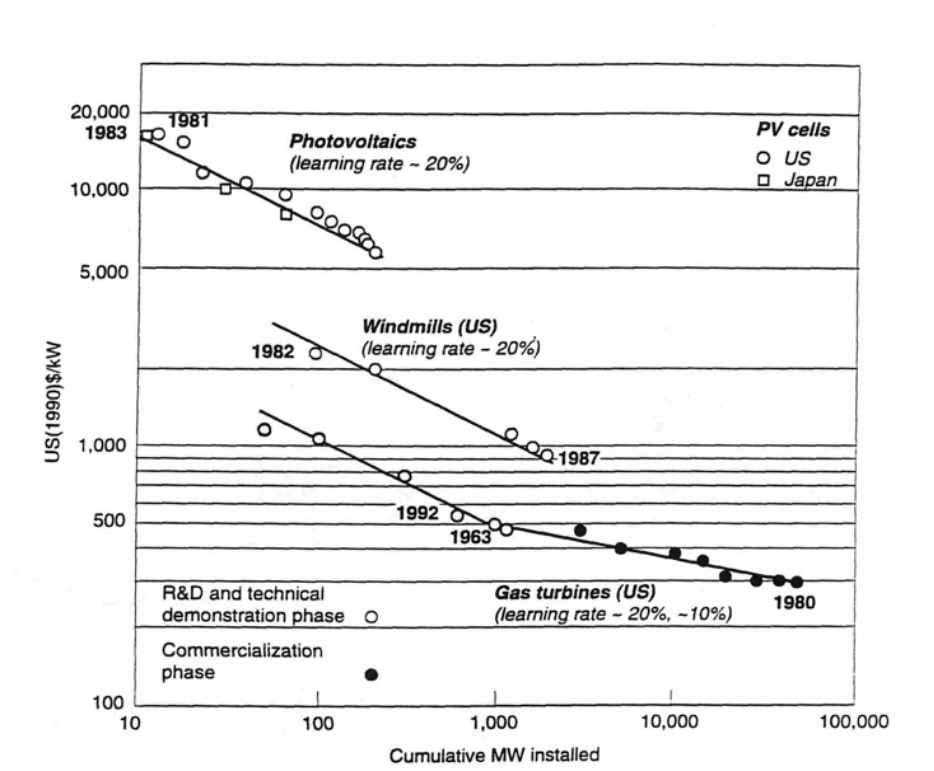

*Figure 5: U.S. public sector energy-related spending on research, development and demonstration (RD&D) since 1980. Source: IEA RD&D database—see the U.S. time series data, total RD&D in million 2017USD at market exchange rates (http://wds.iea.org/WDS/TableViewer/dimView.aspx?ReportId=1399)*

A cornerstone of Stiglitz's opinion is that renewable technologies—zero-emission alternatives—were ripe for increased public-sector investment, and if only the U.S. had made those investments, then renewables would have become a leading source of the U.S. energy supply instead of fossil fuels. Stiglitz's but-for argument is a form of revisionist history that is not supported by the facts of the time.

As illustrated in Figure 6, during the energy crises of the 1970s and 1980s, renewable power was a costly, niche option for energy supply. Specifically, Figure 6 charts time series data on the state of performance for leading wind and solar technologies, as well as for gas turbines there were

[64] Stiglitz comments mainly about "R&D," as a general concept. I use the term RD&D, because for most energy technologies the last "D" is important—demonstration of new concepts at commercial scale is usually needed before the private sector will, on its own, invest in new technologies.

948 also a relatively new technology at the time. Based on my assessment of this chart, I conclude
949 that advances in wind and solar technology have facilitated, and will continue to facilitate,
950 improvements in renewables in the U.S. energy system. However, at the time of the first energy
951 crises in the 1970s, these technologies were cost-prohibitive, and the scale of their performance
952 potential was relatively unknown.
953




954 *Figure 6: Performance (measured in $ capital expenditure for kilowatt of energy output*
955 *potential) over time for leading photovoltaics (also known as solar cells), wind and gas turbine*
956 *technologies. The chart shows the cost of buying each technology, and how cost improved with*
957 *time and investment. The basis for my opinion is the snapshot around 19800s, when solar cells*
958 *approached $20,000 USD/kw, wind was about $3000 USD/kw, and still immature gas turbines*
959 *were more than $1000 USD/kw.*[65] *For comparison, coal fired power plants were, at the time,*
960 *about $700 for coal-fired power plants.*[66] *Put differently, the categories of renewable energy*
961 *technologies that today are most promising (solar and wind) were approximately 25x to 5x the*
962 *capital cost of coal plants. These novel power sources were also less reliable and, in the case of*
963 *gas, burned fuel that was more costly. Source: Arnulf Grubler, Nebojsa Nakicenovic and David*

[65] The study for figure 6 is but one, although a fairly comprehensive review of the literature. More recent retrospectives on renewable technology point to similar findings—for example, the Lantz et al retrospective on wind power, which puts the capital cost of wind projects around 1980 in the US at about $3300/kw (converted to 1990$ with the GDP deflator). See E. Lantz, M. Hand, R. Wiser. The Past and Future Cost of Wind Energy. 2010. NREL Preprint

[66] A major retrospective analysis of coal-fired power plants puts the capital cost at about $1000 USD/kw capacity in the 1970s. That figure is in 2006$, which converted to 1990$ using the GDP deflator (to make it comparable with figure 6) is about $700. For the retrospective see J. McNerney, J.D. Farmer, and J.E. Trancik, "Historical costs of coal-fired electrticity and implications for the future," 39 Energy Policy 3042-3054 (2011).

*G. Victor*, *"Dynamics of energy technologies and global change,"* Energy Policy 27(5):247-280, *1999.*

Stiglitz fails to acknowledge that, in the late 1970s, there was little experience with renewables technology, and what experience did exist suggests such technologies would be substantially more costly than existing commercial rivals. Figure 6 suggests on the order of 10 times more expensive. Further, during this era, the U.S. was already adopting a range of policies aimed at supporting renewables and assisting other low-emission technologies to become cost competitive. For example, in 1978, the U.S. reformed its energy policies to facilitate the entry of new energy technologies, including their ability to connect to the U.S. power grid.[67] In addition, the U.S. was actively supporting nuclear power, efficiency, fuel cells and other major options.

**Finding #7. ERRORS OF OMISSION: CLIMATE CHANGE REQUIRES INTERNATIONAL COOPERATION, WHICH IS A MATTER FOR WELL-PROSECUTED FOREIGN POLICY**

In my expert opinion, effective solutions to mitigate the adverse impacts of climate change necessitate engaged cooperation between the U.S. and its international partners. My review of the expert reports submitted by Erickson and Stiglitz fail to adequately address the importance of international cooperation in addressing climate change. The omission by Erickson and Stiglitz to address the importance of international cooperation in addressing climate change leads to misleading conclusions about the breadth and scope of the challenges associated with slowing and reversing climate change, and the role of the U.S. in redressing these challenges. Below, I discuss the basis for my opinion

First, technologies and fuels are traded globally. GHGs, once emitted, mix globally, as does the heat created when those GHGs alter the climate. As such, the capacity of the U.S. to alter the global trajectory of climate change through unilateral domestic action is limited. For example, assume the U.S. government unilaterally ceased all emissions contributions from its own footprint. The countervailing impact of its actions would be to reduce global emissions by less than 1%, which is less than the annual change in global emissions between 2011 and 2012.[68]

[67] See the Public Utility Regulatory Policies Act (PURPA), Pub. L. 95-617, 92 Stat. 3117, 16 U.S. Code 46 § 2601 et seq, enacted November 9, 1978.

[68] The U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy (EERE) publishes annual Federal Agency Greenhouse Gas Inventory data at http://ctsedwweb.ee.doe.gov/Annual/Report/ComprehensiveGreenhouseGasGHGInventoriesByAgencyAndFiscalYear.aspx. These data indicate that 2012 greenhouse gas emissions across all Federal Agencies totaled 164.39 million metric tons of CO2 equivalent. This number can be calculated by summing the subtotals for Scope 1 (15.188 and 45.623 and 0.831 million metric tons), Scope 2 (30.4 and 0.89 and 1.912 million metric tons) , and Scope 3 (16.537 and 52.683 and 0.326 million metric tons) emissions across all three of the emissions categories provided. The EDGAR 4.2 FT2012 (all GHGs) dataset, referenced as the source for Figure 2 earlier in this Expert Report, does not provide data beyond 2012; its estimate for global GHG emissions as of 2012 is 53,526.3028283888 million metric tons. Dividing approximately 161 million by approximately 53,526 million yields approximately 0.003, or 0.3% of global emissions. By comparison, the EDGAR data used in this Expert Report as a reference for Figure 2 indicate a year-over-year change in total global greenhouse gas emissions between 2011 and 2012 of 1.39 percent, or approximately 52,791 million metric tons in 2011 to 53,562 million metric tons in 2012.

Further, assume that the U.S. economy as a whole eliminated all of its territorial emissions contributions, which in 2012 accounted for 12% of global emissions. That 12% reduction would be offset to some degree by countervailing responses in other countries. Lower US demand for fuels, such as oil could lower the global price for oil and raise consumption and emissions in other countries. Higher costs of industrial production in the US due to higher energy costs could shift industrial activity to other countries, leading to expanded consumption of fossil energy and emissions abroad. Higher demand in the US for renewable energy technologies and other elements of a zero emission energy system could raise the price of those technologies globally, leading to reduced use abroad and higher emissions. Deriving a quantitative measure of such impacts requires understanding of how the global markets and other governments would respond to such actions. Stiglitz offers no such estimate for the size of these countervailing responses, except to say that "U.S. emissions will not be perfectly offset," (page 41) a statement for which he cites a study that does not examine the extreme scenario he contemplates. Nor does Stiglitz offer any other citations to supporting literature or analysis; he also does not acknowledge that even a complete cessation of US emissions without any offsetting effect would alter global emissions only 12%.

Stiglitz suggests in his Expert Report that if the U.S. were to lead with extreme action, such as ceasing approval for any new fossil fuel infrastructure, that others nations would follow.[69] Stiglitz does not quantify the magnitude of this effect, nor does he offer guideposts to estimate the possible impacts. My review of academic studies that have examined the effects of leadership in areas where countries already are instituting reductions in emissions suggests that leadership, in fact, does not automatically generate followership.[70] Leadership without cooperation and coordination can be counter productive, reducing the impact of unilateral actions on emissions. Failure to demonstrate cooperation in tandem with leadership can also undermine political support needed to sustain emissions controls.

Second, international cooperation requires international institutions for cooperation, including venues to encourage dialogue and treaties to foster engagement. The U.S. has been at the forefront of efforts to build those institutions. For example, the U.S. has been a seminal participant in the IPCC.[71] The U.S. also was one of the key architects of the 1992 Framework Convention on Climate Change, and served as a leading force (along with China and France) in creating the 2015 Paris Agreement.[72]

[69] See page 41. Stiglitz asserts that, because the U.S. is a big emitter leadership though its actions "has a significant impact on these global outcomes", referring to the outcomes of lower emissions globally, and the avoidance of an offsetting "leakage" of emissions to other jurisdictions.

[70] David G. Victor et al., "Turning Paris into reality at the University of California," *Nature Climate Change* 8:183-185, 2018. Robert O. Keohane and David G. Victor, "Cooperation and Discord in Global Climate Policy," Nature Climate Change. 2016. DOI: 10.1038/NCLIMATE2937

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In my opinion, mitigating climate change requires the committed engagement of the U.S. and its international partners. I believe that the measured progress realized to date reflects mainly the complexity and political challenges associated with crafting effective international cooperation, rather than neglect of the topic by the U.S. government. It is my expert opinion that the simplistic and narrowly-focused approaches posited by Stiglitz and Erickson with respect to U.S. engagement—which advocate unilateral action and gloss over the challenges inherent to international engagement and cooperation—fail to respect the global nature of the problem, the need for an integrated, portfolio-based solution and the essential role for diplomacy in the process of implementing that solution.

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## V. COMPENSATION

My preparatory rate for expert services in this case is $325/hour. My Testimony or Deposition rate is $350/hour.

I have not testified as an expert at trial or by deposition within the preceding four (4) years.

**Appendix A: CV**

**DAVID G. VICTOR**

**A. PROFESSIONAL PREPARATION:**
Harvard University, History and Science, A.B., 1987
Massachusetts Institute of Technology, Political Science, Ph.D., 1997

**B. APPOINTMENTS:**
University of California, San Diego
Professor, School of International Relations and Pacific Studies, 2009 to present
Director, Laboratory on International Law and Regulation, 2009 to present
Stanford University
Professor, School of Law, 2006-2009
Director, Program on Energy and Sustainable Development, 2001-2009
Council on Foreign Relations, New York
Robert W. Johnson, Jr., Senior Fellow for Science and Technology, 1998-2009
International Institute for Applied Systems Analysis, Laxenburg, Austria
Research Scholar, Project on "Environmentally Compatible Energy Strategies, 1997-1998
Co-Leader, Project on "Implementation and Effectiveness of International Environmental Commitments (IEC)", 1993-1997

**C. PRODUCTS**

**1. Five Most Relevant Products**
[1] David G. Victor, 2011, *Global Warming Gridlock: Creating More Effective Strategies for Protecting the Planet* (Cambridge: Cambridge University Press).
[2] Oil and Governance: State-Owned Enterprises and the World Energy Supply*, Cambridge: Cambridge University Press* (with David Hults and Mark Thurber, eds). 2012.
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**2. Other Significant Products**
[1] "The Cognitive Revolution and the Political Psychology of Elite Decision Making," *Perspectives on Politics*, 11(2013): 368-386. (with Emilie Hafner-Burton and Alex Hughes)
[2] "Politics and Economics of Second-Best Regulation of Greenhouse Gases: The Importance of Regulatory Credibility," *Energy Journa*l, 32(2011): 1-24. (with Valentina Bosetti)

[3] "A Madisonian Approach to Climate Policy," *Science*, 309(2005): 1820-1821. (with Joshua House and Sarah Joy)

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[5] Markets in Developing Countries: Politics, Law and Institutions, *Cambridge: Cambridge University Press*. (with Thomas Heller, eds.)

**D. SYNERGISTIC ACTIVITIES:**

**1. Selected awards**

Heinz I. Eulau Award, American Political Science Association, 2012.
Convening Lead Author, Intergovernmental Panel on Climate Change, 2011-2014.

**2. Selected Fellowships and Lectures**

Keeling Lecture, Scripps Institution of Oceanography, April 2014
Harold Jacobson Lecture, Institute for Social Research, University of Michigan, October 2013.
Banco Mundial lecture, Sao Paulo, Brazil. March 2013.
Energy Forum Lecture, University of Texas, Austin. February 2012.
Research Institute of Innovative Technology for Earth featured speaker, Tokyo, Japan. February 2013.
Electric Power Research Institute keynote speaker, Summer Seminar, August 2012.
Cochrane Lecture, University of Minnesota. January 2010.
Observer Research Foundation plenary lecture, September 2008.

**3. Professional Activities**

American Association for the Advancement of Science
American Political Science Association
American Geophysical Union
American Society of International Law
International Studies Association
International Institute for Strategic Studies

**4. Editorial activities**

Editorial Boards: *Climatic Change* (Deputy Editor responsible for most submissions in the social sciences). Oxford University Press *Encyclopedia of Global Change. Chinese Academy of Social Sciences, Sustainable Development Research. Nature Climate Change. Energy Research and Social Science.*
Reviewer (selected): *American Journal of International Law. American Journal of Political Science. American Political Science Review. Climatic Change. Comparative Political Studies. Governance. International Studies Quarterly. Journal of Energy Policy. Journal of Politics. Nature. Review of International Studies. Regulation and Governance. Science. World Politics.*

**E. COLLABORATORS AND OTHER AFFILIATIONS**

**1. Collaborators and coauthors in past 48 months**

Valentina Bosetti (FEEM), Emilie Hafner-Burton (UCSD), David Hults (Stanford Law School), Charles Kennel (SIO/UCSD), Robert Keohane (Princeton), Yonatan Lupu (GWU), Fang Rong (UCSD), Varun Rai (UT-Austin), V. (Ram) Ramanathan (SIO/UCSD), P.R. Shukla (IIMA), Barton Thompson (Stanford Law School), Mark Thurber (Stanford), Kassia Yanosek (McKinsey and Company).

**2. Graduate advisors**

Eugene B. Skolnikoff (MIT), Abraham Chayes (Harvard), Kenneth Oye (MIT).

**3. Ph.D. advising**

Jeremy Carl (Stanford), Danny Cullenward (Stanford), Yassir Eddebarr (UCSD), Stephie Fried (UCSD), Ryan Hanna (UCSD), Mark Hayes (Stanford), Lukas Nonnemacher (UCSD), Daniel Maliniak (UCSD), Peter Kannberg (Scripps Institution of Oceanography), Wei Peng (Princeton), Varun Rai (Stanford), Tamara Sheldon (UCSD), Yanyang Xu (UCSD).

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